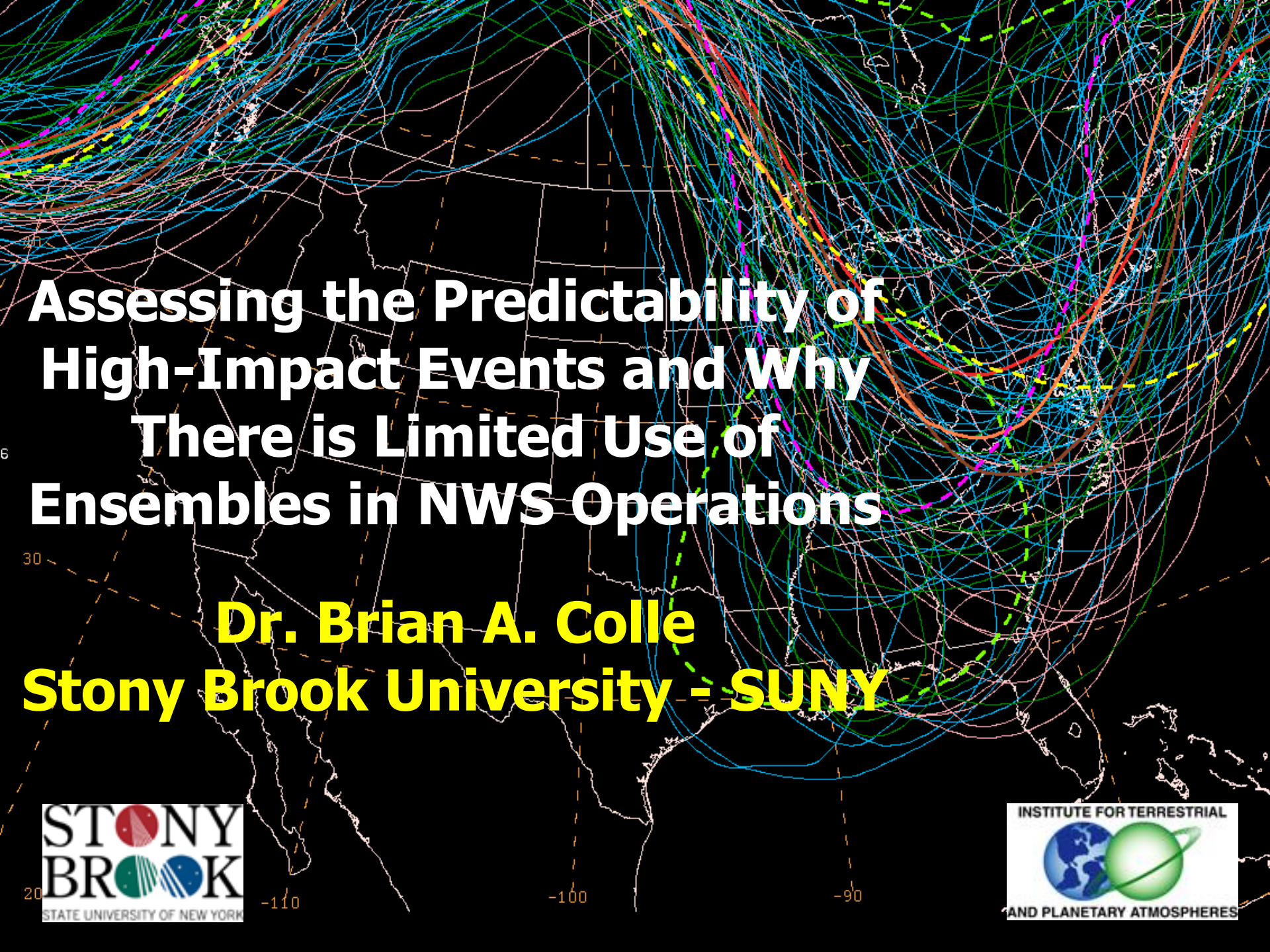


Assessing the Predictability of High-Impact Events and Why There is Limited Use of Ensembles in NWS Operations

Dr. Brian A. Colle
Stony Brook University - SUNY

STONY BROOK
STATE UNIVERSITY OF NEW YORK

INSTITUTE FOR TERRESTRIAL AND PLANETARY ATMOSPHERES

This work highlights a CSTAR project (2010-2013): Predictability of High Impact Weather during the Cool Season over the Eastern U.S

Brian A. Colle and Edmund Chang
Stony Brook University - SUNY

HPC – David Novak et al.

EMC – Yuejian Zhu, Yan Luo, Jun Du, and Jordan Alpert

OPC – Joseph Sienkiewicz et al.

WFO-OKX: Jeff Tongue et al.

WFO-PHI: Al Cope et al.

WFO-CTP: Richard Grumm et al.

WFO-PIT: Josh Korotky et al.

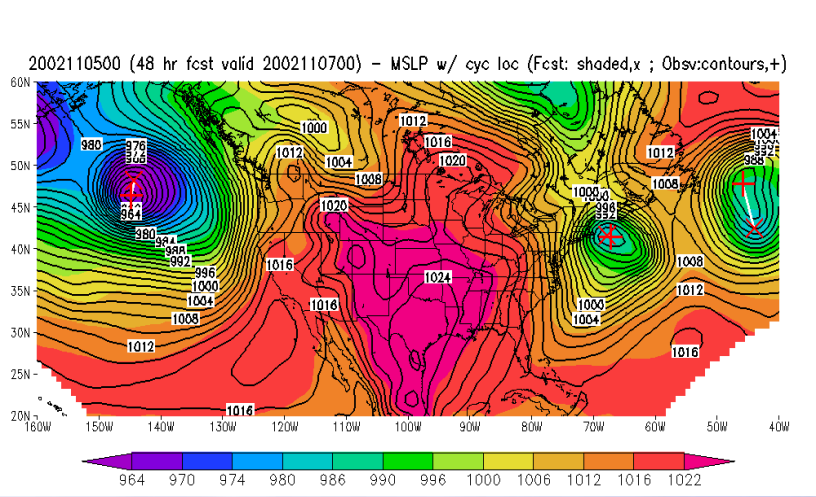
STONY BROOK
STATE UNIVERSITY OF NEW YORK

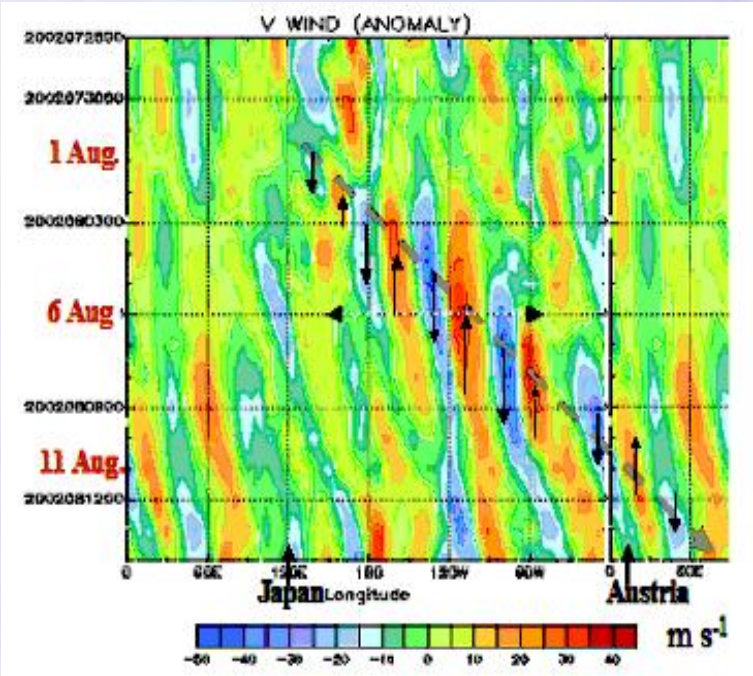
INSTITUTE FOR TERRESTRIAL AND PLANETARY ATMOSPHERES

http://dendrite.somas.stonybrook.edu/CSTAR/cstar.html

CSTAR Scientific Motivation

* Improve the understanding of high impact weather predictability during the cool season through objective verification of cyclones and Rossby wave packets (RWPs) in ensembles.
* Better understanding of RWPs in relation to extreme weather.
* Better understanding of the predictability of some mesoscale phenomena (e.g., snowbands).
* Better ensemble tools and post-processing.





From THORPEX International Science Plan (Shapiro and Thorpe, 2004)

Talk Outline

1. Some current ensemble tools/programs used in the NWS forecast offices.

2. Some issues using ensembles in operations: Survey results

3. New tools Part 1: Rossby wave packets

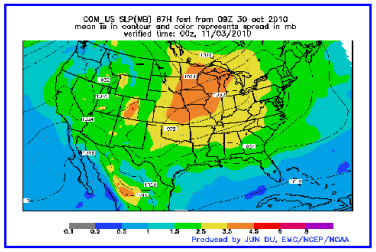
4. New tools Part 2: Real-time ensemble sensitivity analysis

The operational community has made significant progress in ensemble modeling and products during the last decade

SHORT-RANGE ENSEMBLE FORECASTING (S

Take COMET "Ensemble Forecasting" online course by clicking here

UCAR Ensemble Page



ENSEMBLE PREDICTION SYSTEMS

A basic training manual targeted for operational meteorologists

"Unfortunately when you most need predictability, that's usually when the atmosphere is most unpredictable." - C

NCEP ENSEMBLE PRODUCTS

This NCEP Ensemble Home Page is a collection of experimental analysis and forecast products produced by the GFS-based Ensemble forecast system.

Forecast Plots

Probabilistic Precipitation Forecasts *DETAILS* 24-hr Precip Evaluation 6 Hr PQPF Types	Relative Measures of Predictability *DETAILS*	Ensemble Mean and Spread Plots *DETAILS*	Ensemble Spaghetti *DETAILS* Parallel Spaghetti *(latest ended 03/09/04)*	Cyclone Tracking Strike Probabilities	Wave Ensemble

FSU/NWS TLH COMET Experimental Forecast Confidence Graphics

Robert Hart and Andrew Durante, Florida State University
Irv Watson, SOO, NWS TLH
Richard Grumm, SOO, NWS CTP
Walter Drag, SF, NWS BOX

ast confidence measures using NCEP Ensembles. The end goal is to implement these measures for real-time us
e detailed discussion of the project and its goals, along with answers to frequently asked questions can be found

ental and not official forecasts. For official forecasts in the U.S., please refer to the National Weather Service

d a 5-day forecast confidence map from the latest GFS ensemble run. Links to other forecast times are available

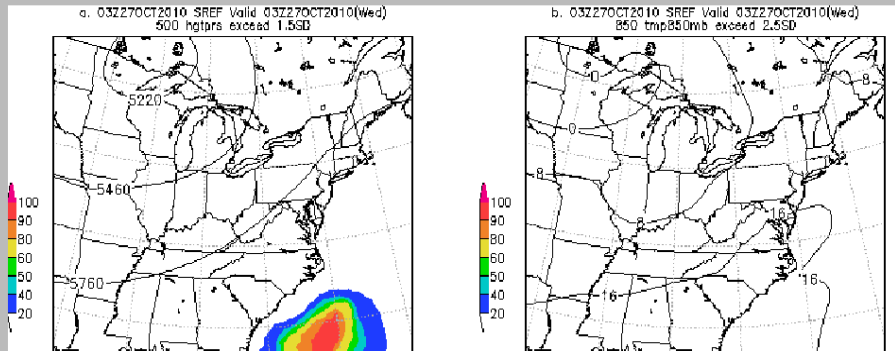
Confidence graphics/research presented at the 86th AMS Annual Meeting in Atlanta, GA

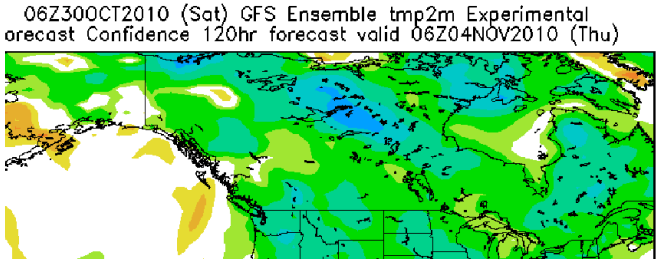
Confidence Discussion

Ensemble Threats Forecast & archive veiwer

Select speed: normal Animation toggle

Select EFS: SREF
Select a Date: 20101027
Select Projection: EAST
Select a Cycle: 03
Select a Parameter: heat



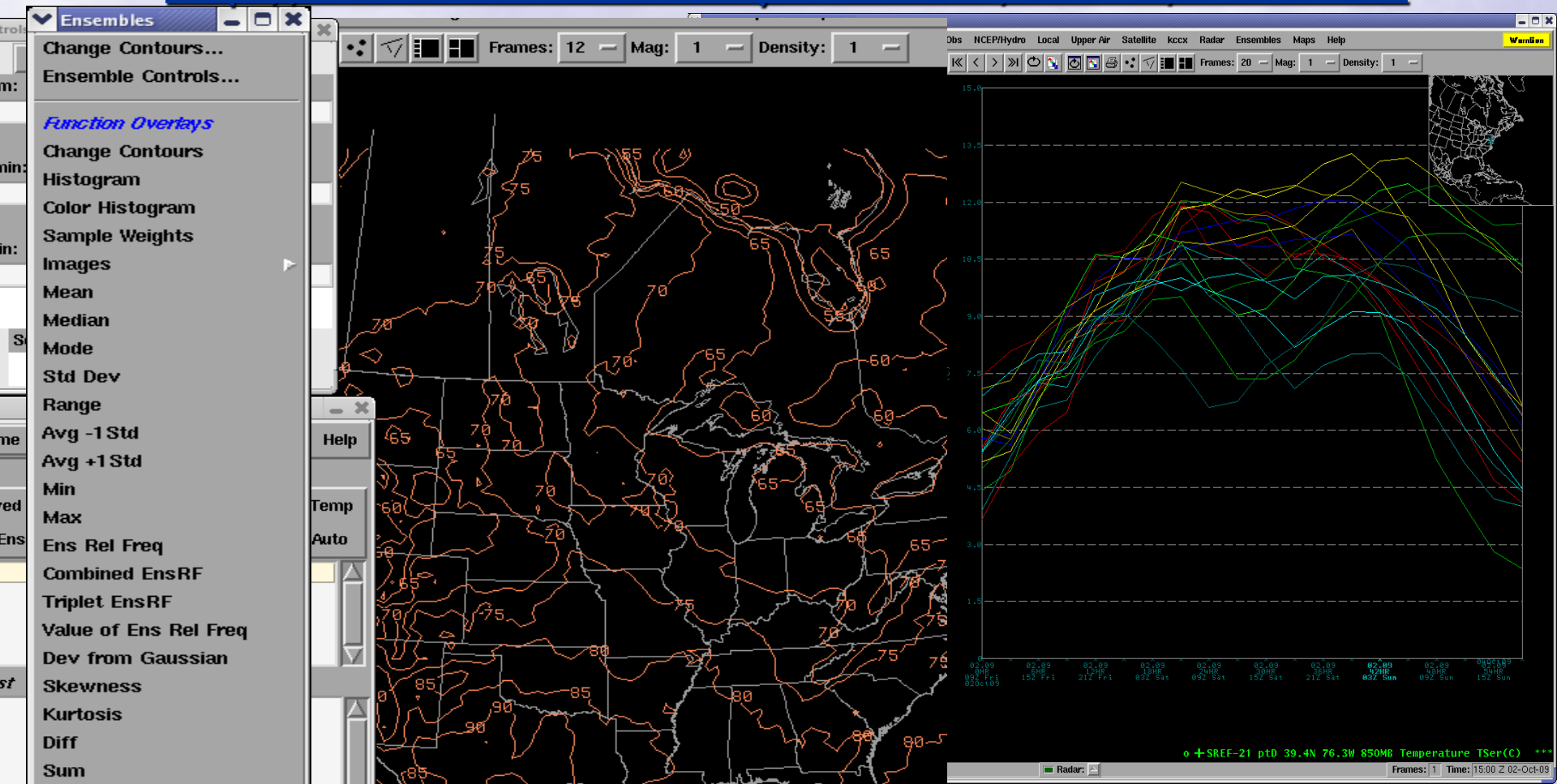


Some progress displaying ensemble data in the forecast office for CSTAR.

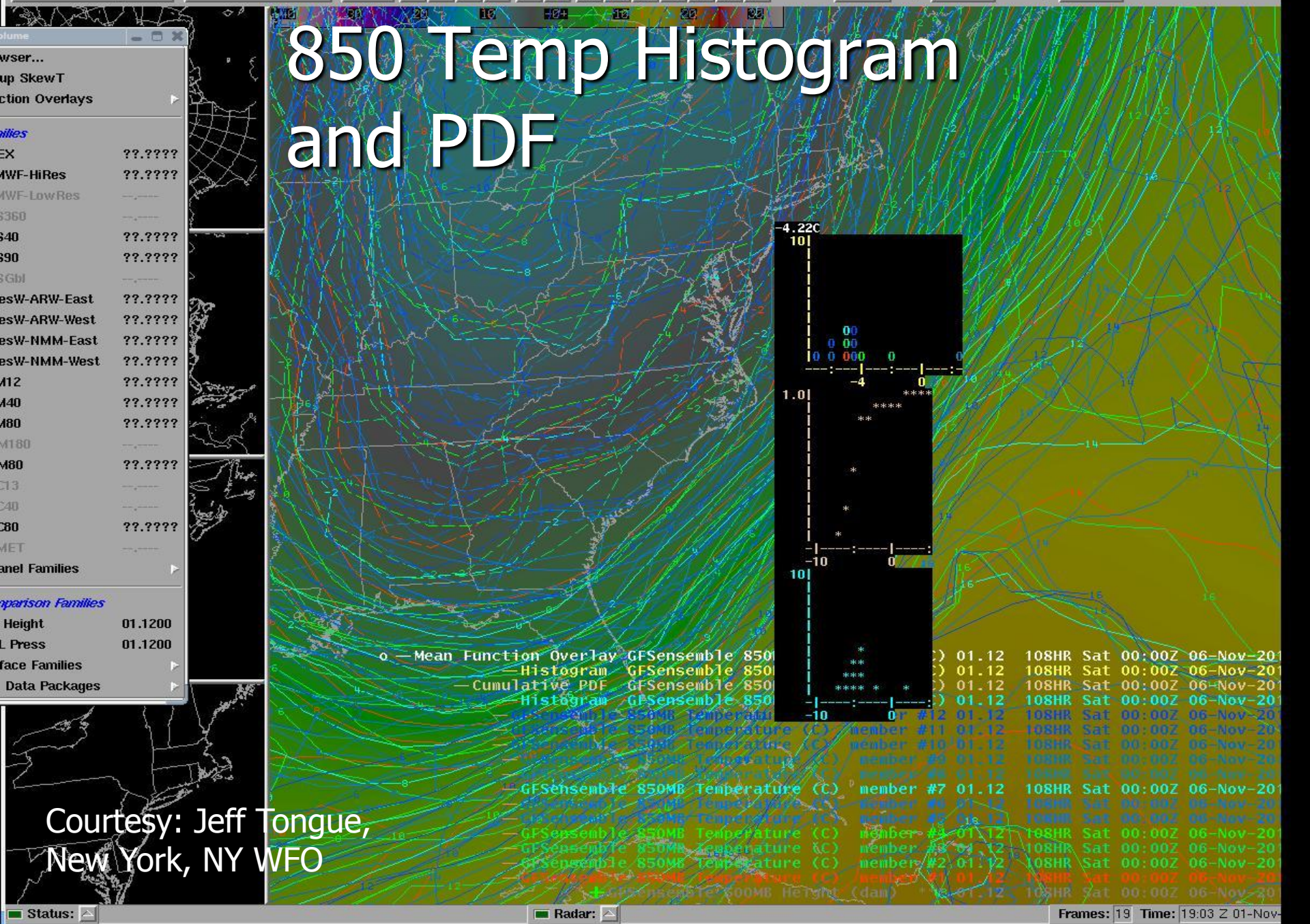
Advanced Linux Prototype System (ALPS)

http://www-sdd.fsl.noaa.gov/~ramer/alps/ensembles/ensembles.html

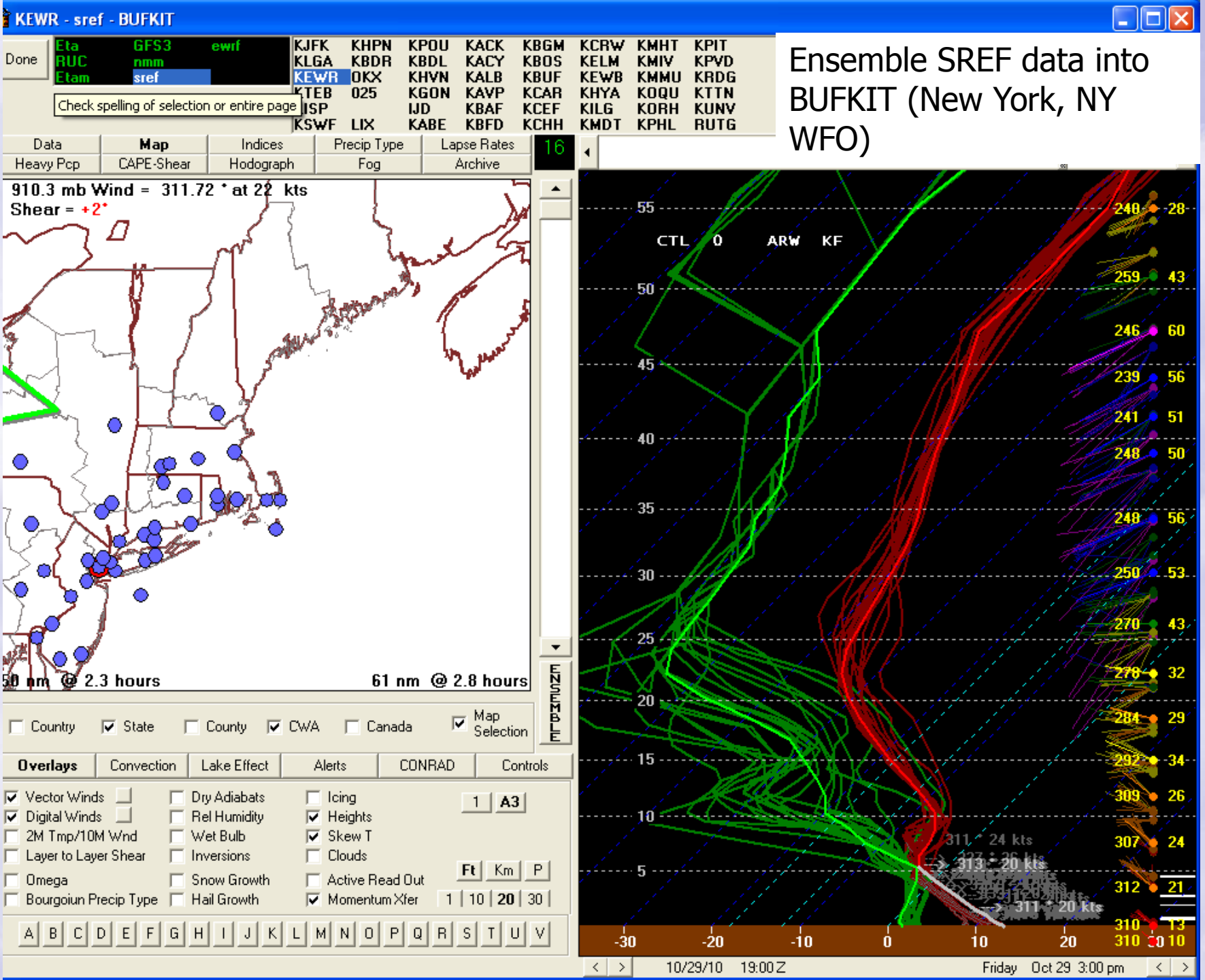
http://dendrite.somas.stonybrook.edu/CSTAR/ALPS.html



850 Temp Histogram and PDF



Courtesy: Jeff Tongue, New York, NY WFO



Ensemble SREF data into BUFKIT (New York, NY WFO)

What are some of the current challenges in using ensembles in operations?

* Ensemble underdispersion (lack of calibration) and biases limit ensemble skill.
* Ensembles have not been comprehensively verified, especially for high impact weather.
* Forecasters lack tools to understand the origin of ensemble spread and errors in realtime.
* Forecasters have few ways to communicate uncertainty in their public forecast products

Novak, David R., David R. Bright, Michael J. Brennan, 2008: Operational Forecaster Uncertainty Needs and Future Roles. *Wea. Forecasting*, **23**, 1069–1084.

Survey: To rank these potential issues of using ensembles in operations:

Survey Questions:

1. What is your current position? (operational forecaster, manager/admin, researcher, and model developer)
2. How often do you use ensembles?
3. Why are ensembles not used in operations as much as they could be? Weight each issue from "not a problem" (= 1) to "one of the largest problems" (= 5)
4. Rank the 8 provided issues from the largest problem to the smallest issue/problem.
5. Open Ended Question: Other written comments regarding the difficulty in using ensembles in operations.

Ensemble Issues To Rate/Weight

* Data Access. Not enough ensemble data is making it into the forecast office.
* There is limited time to view and interpret ensembles.
* Most clients and/or NWS grids do not require enough probabilistic information.
* Ensemble means/probabilities have relatively large errors and are uncalibrated.
* Ensemble resolution is too coarse.
* Not enough probabilistic verification has been done.
* Lack of training in ensembles.
* Lack of graphics/tools to interpret ensemble predictions.

Survey open from 9 November 2011 to 15 December 2011. Sent to all NWS SOOs (many forwarded to other forecasters), managers, and model developers within the NWS, as well as 15-20 faculty/students at universities doing ensemble research.

* The results in the following slides are separated into the following sections. Number of responses are in the ( )

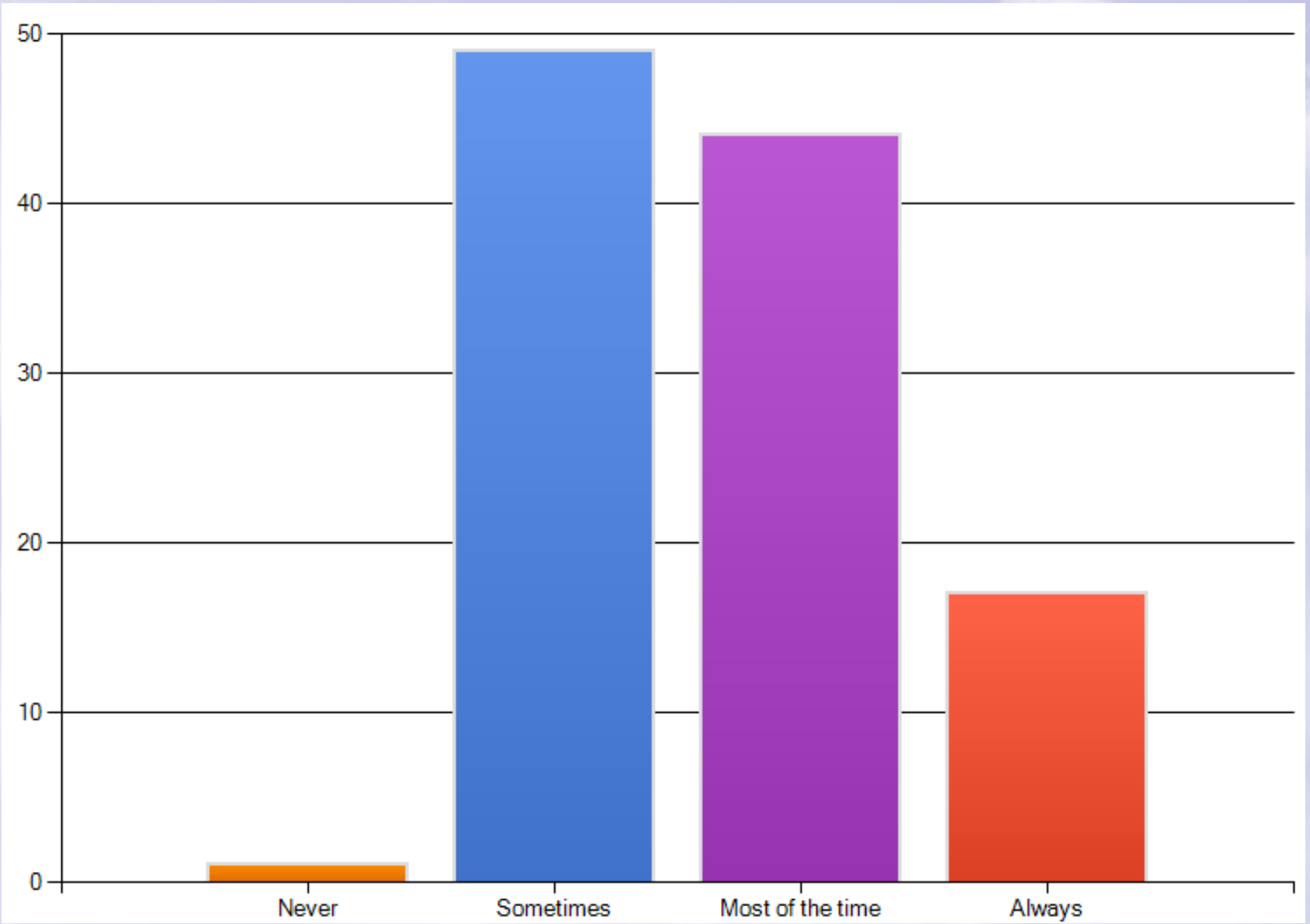
1. All responses (166)
2. Operational NWS Forecasters (111)
3. NWS Admin / Managers (37)
4. Researchers and Model Developers (18)
5. NWS Forecasters who sometimes or never use ensembles (50)
6. NWS Forecasters who use ensembles often or always (61)

For the full survey results, please check out:

http://dendrite.somas.stonybrook.edu/CSTAR/Surveys.html

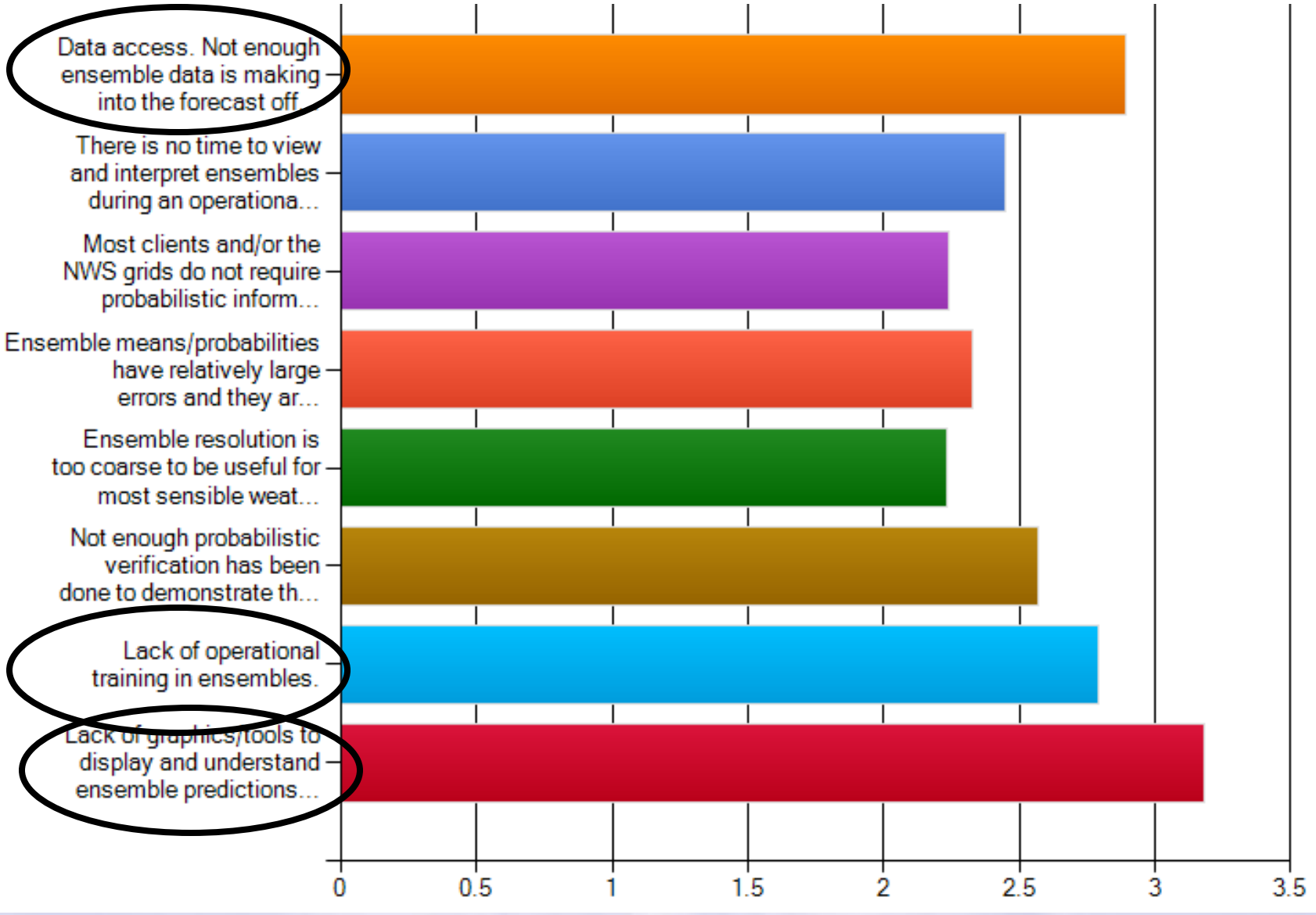
Operational Forecaster Results

How often do you use ensembles?

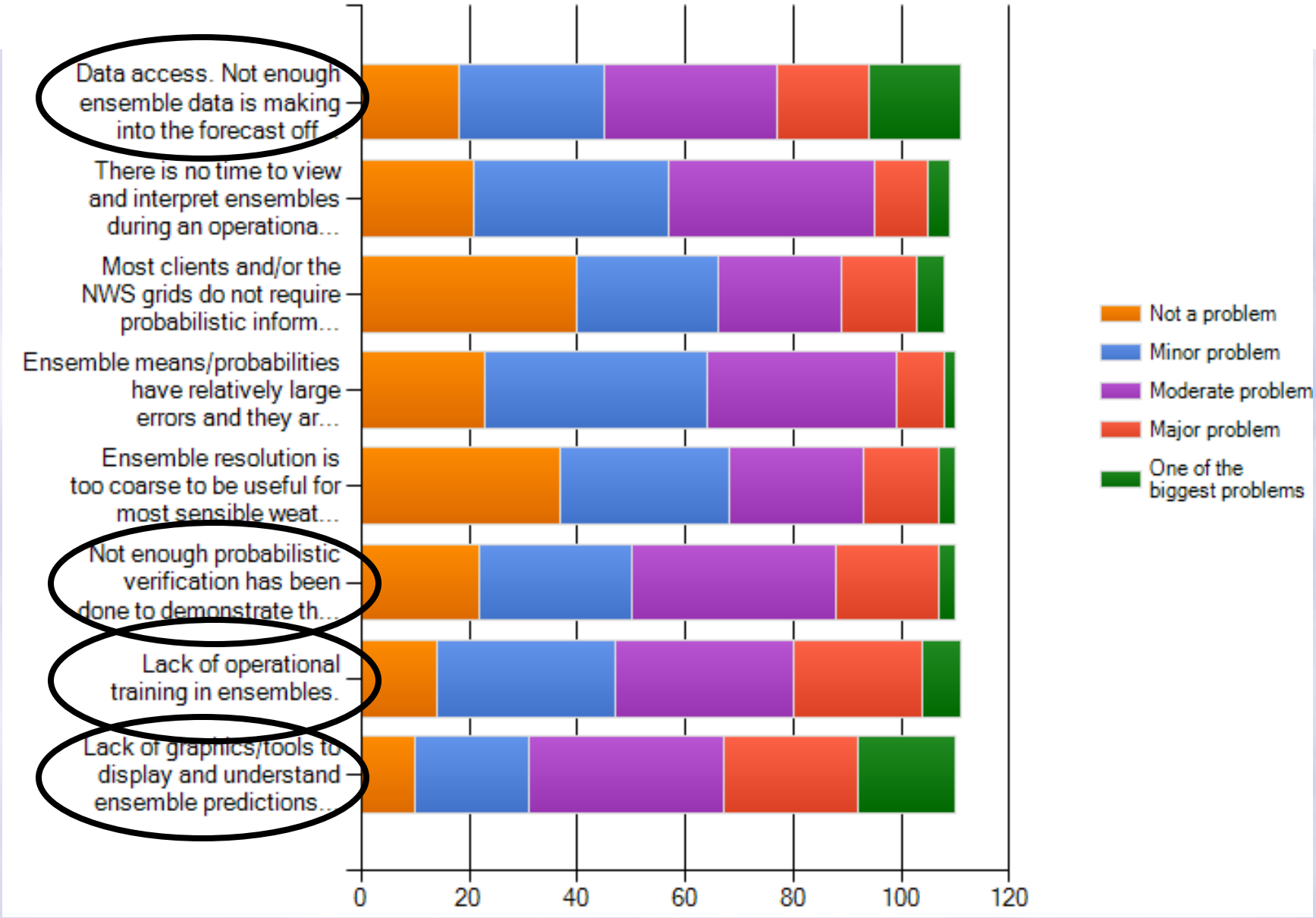


Why Ensembles not used in operations? (average response)

(1=Not a problem, 2 = Minor, 3= Moderate, 4 = Major, 5= One of Biggest)

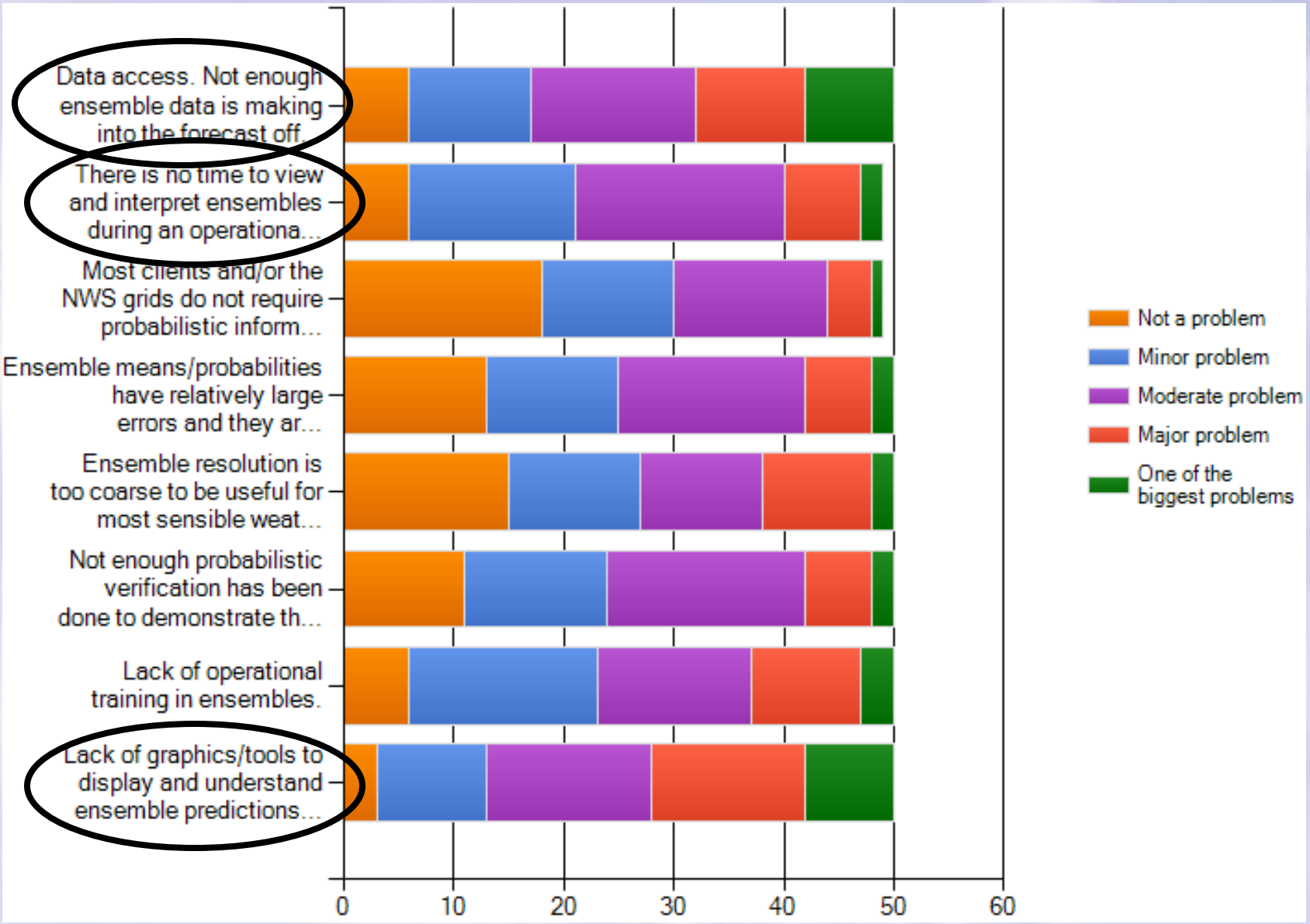


Why Ensembles not used in operations as much as they could be?
(Number of responses:No problem, Minor, Moderate, Major, Biggest)



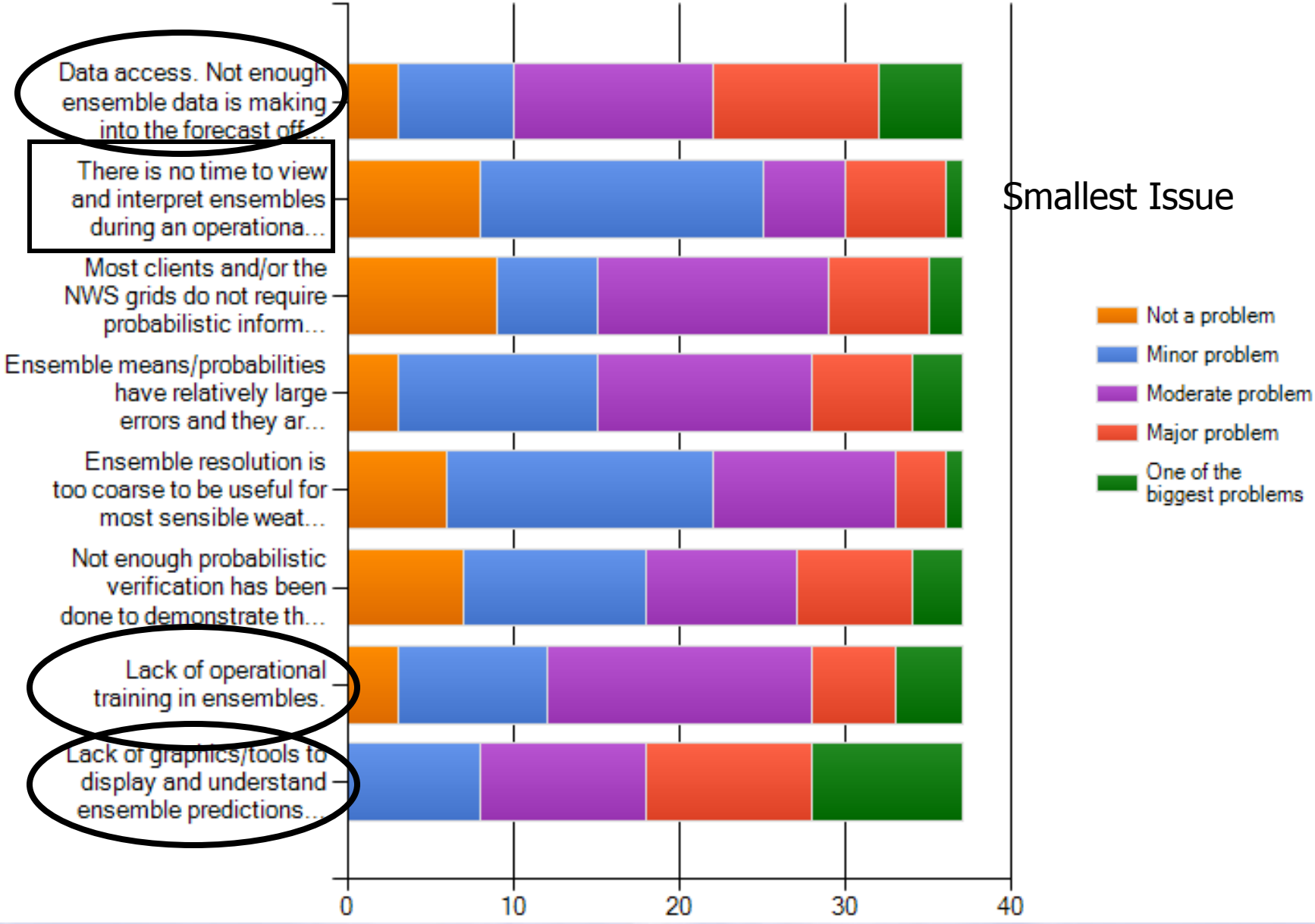
Forecasters who only sometimes use ensembles

(Number of responses:No problem, Minor, Moderate, Major, Biggest)



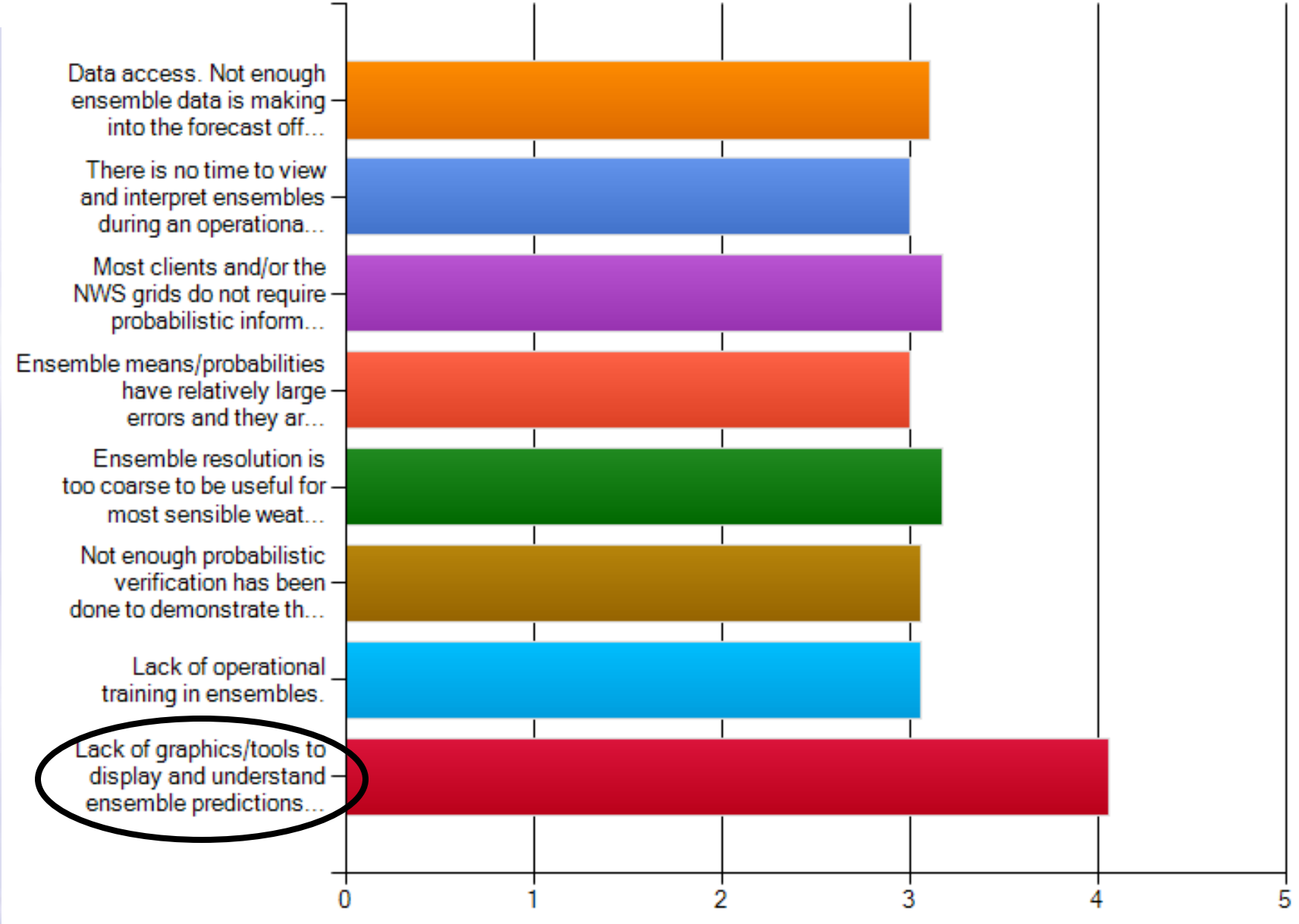
Manager/Admin Results Only

Why Ensembles not used in operations as much as they could be?
(Number of responses: No problem, Minor, Moderate, Major, Biggest)



Researcher / Model Developer

Why Ensembles not used in operations as much as they could be?
(1=Not a problem, 2 = Minor, 3= Moderate, 4 = Major, 5= One of Biggest)



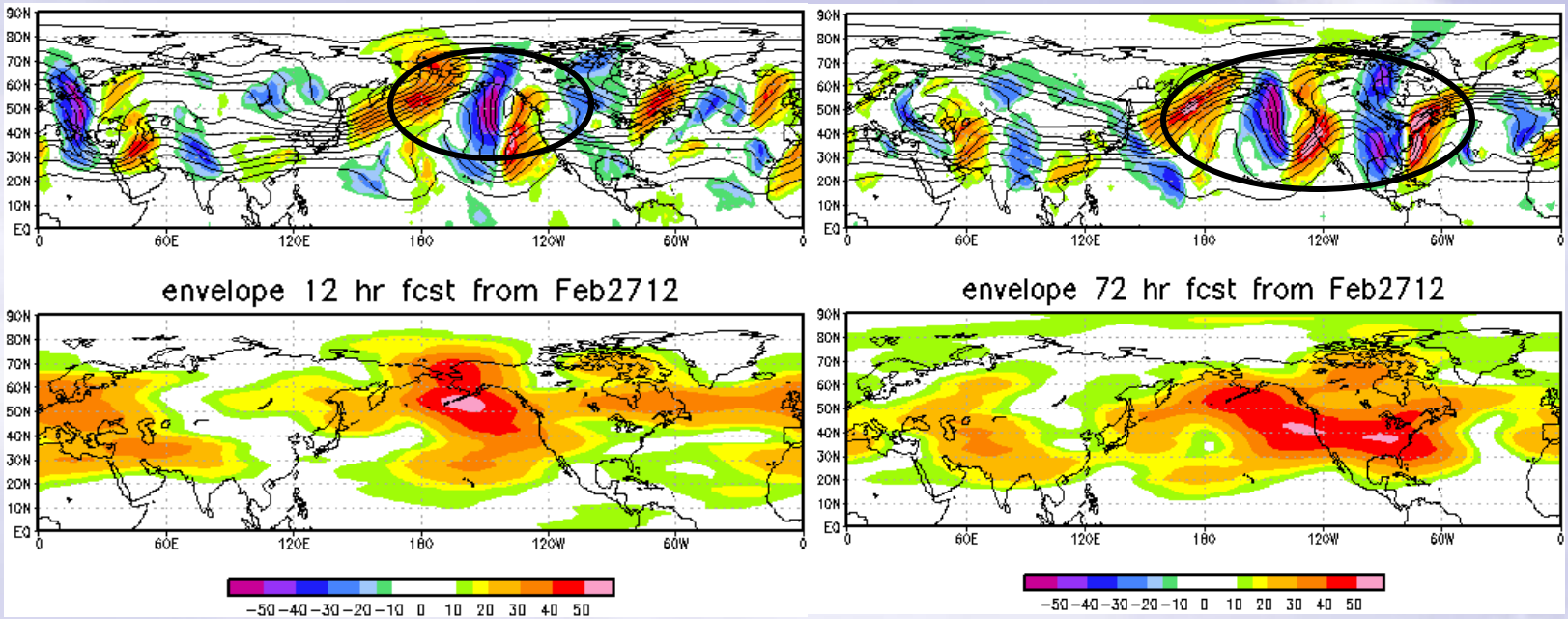
Survey Summary

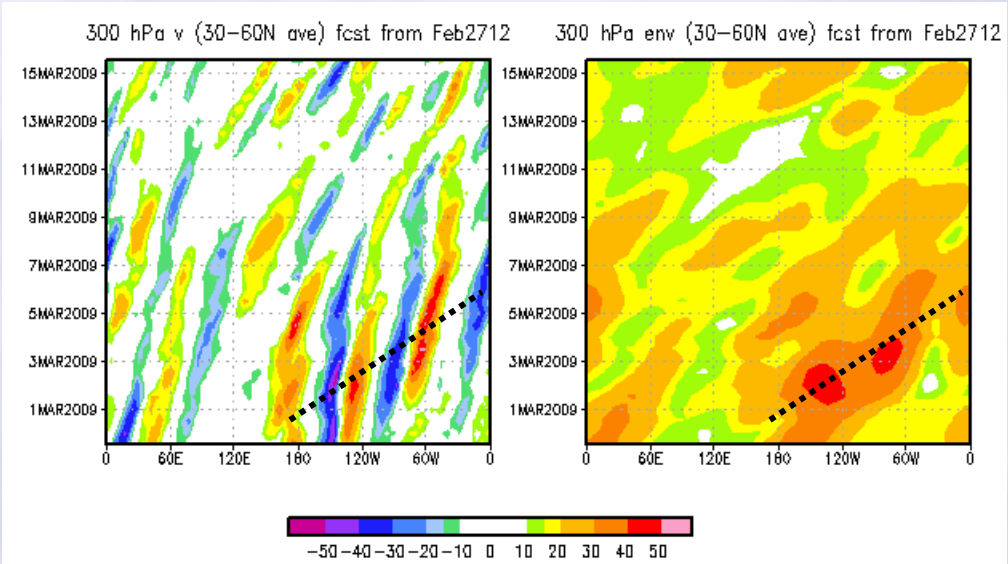
* Nearly all forecasters use ensembles; however, only ~45% use them "sometimes."
* The highest ranked issues are (1) the lack of tool/graphics, (2) ensemble data access, and (3) ensemble training.
* For forecasters who "sometimes use ensembles," it appears that the time to view/interpret ensembles is also an issue (ranked #3). Some of this may be from the lack of tools and data access as suggested by their open ended questions.
* Managers/admin view the time to interpret ensembles as the smallest problem on average (rank #8).
* Most or all researchers and model developers believe that the lack of tool/graphics is the largest issue.

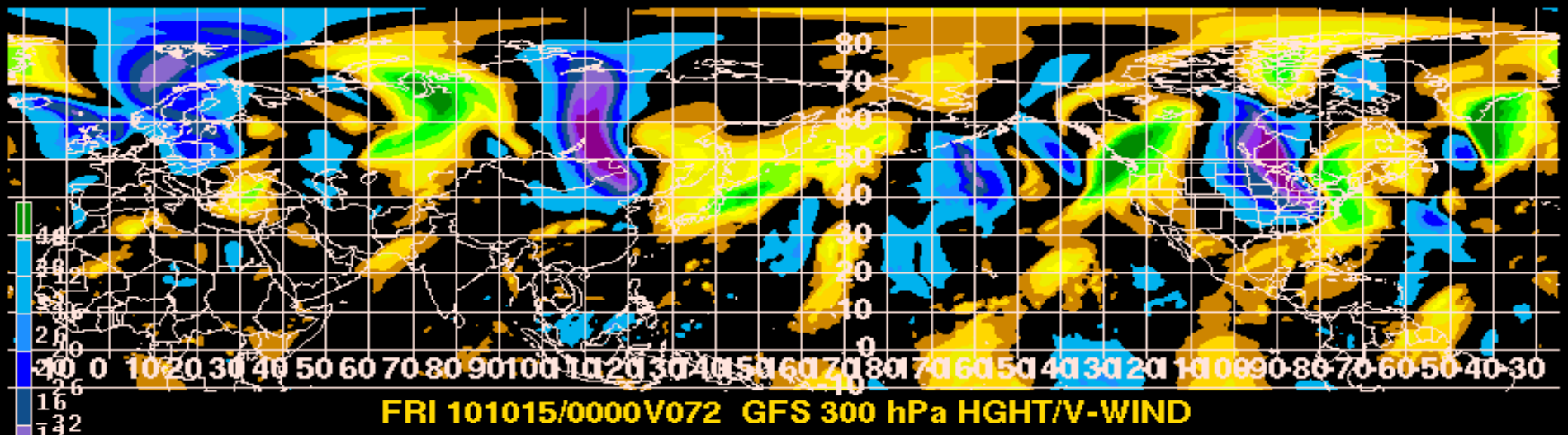
Need more ensemble tools to better engage forecasters with ensembles and understand predictability issues in realtime.

Stony Brook Wave Packet Diagnostics for Winter TPARC

http://xs1.somas.stonybrook.edu/~chang/personal/Wave/main.htm

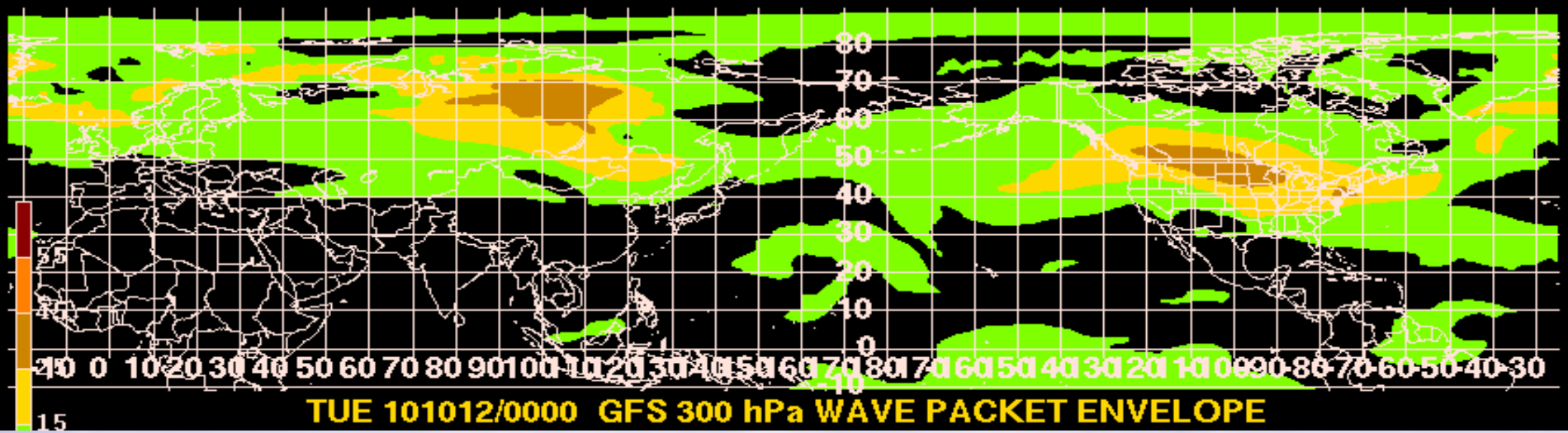






Stony Brook Univ. – NCEP-HPC collaboration:
Real-time Wave Packets in Operations

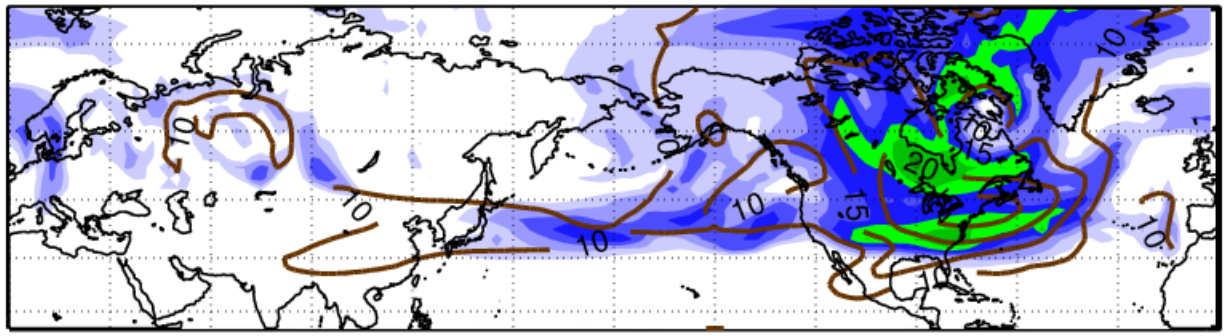
Courtesy: Mike Bodner at HPC



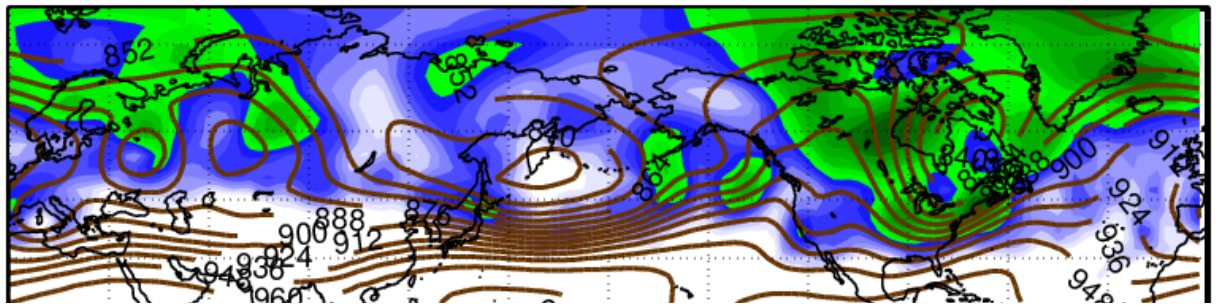
Ensemble (GEFS) Wave Packets

http://wavy.somas.stonybrook.edu/wavepackets/home.html

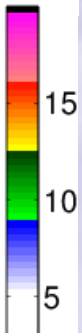
Model Initialized: 2012020700 Valid h+120

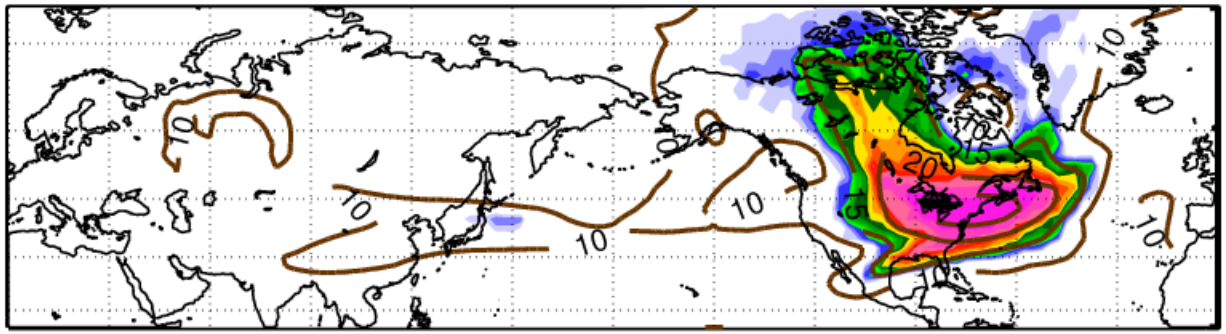


300 hPa Wave Packet Amplitude (WPA in m/s) and spread (shaded)

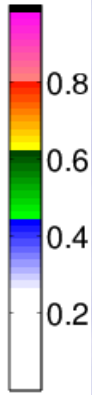


300 hPa heights and spread (shaded in dm)

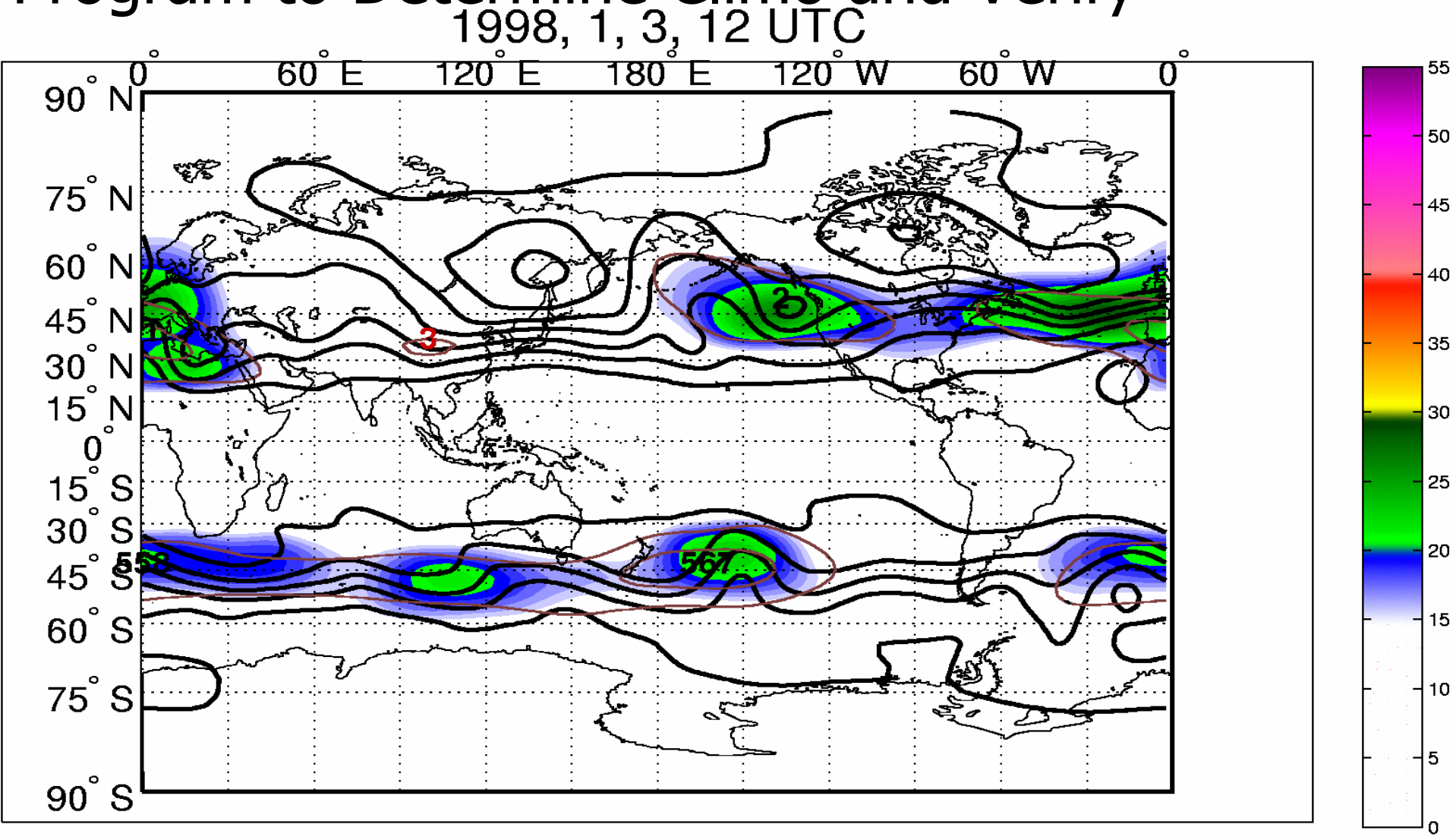




Mean WPA And Prob (*100) of WPA > 15 m/s

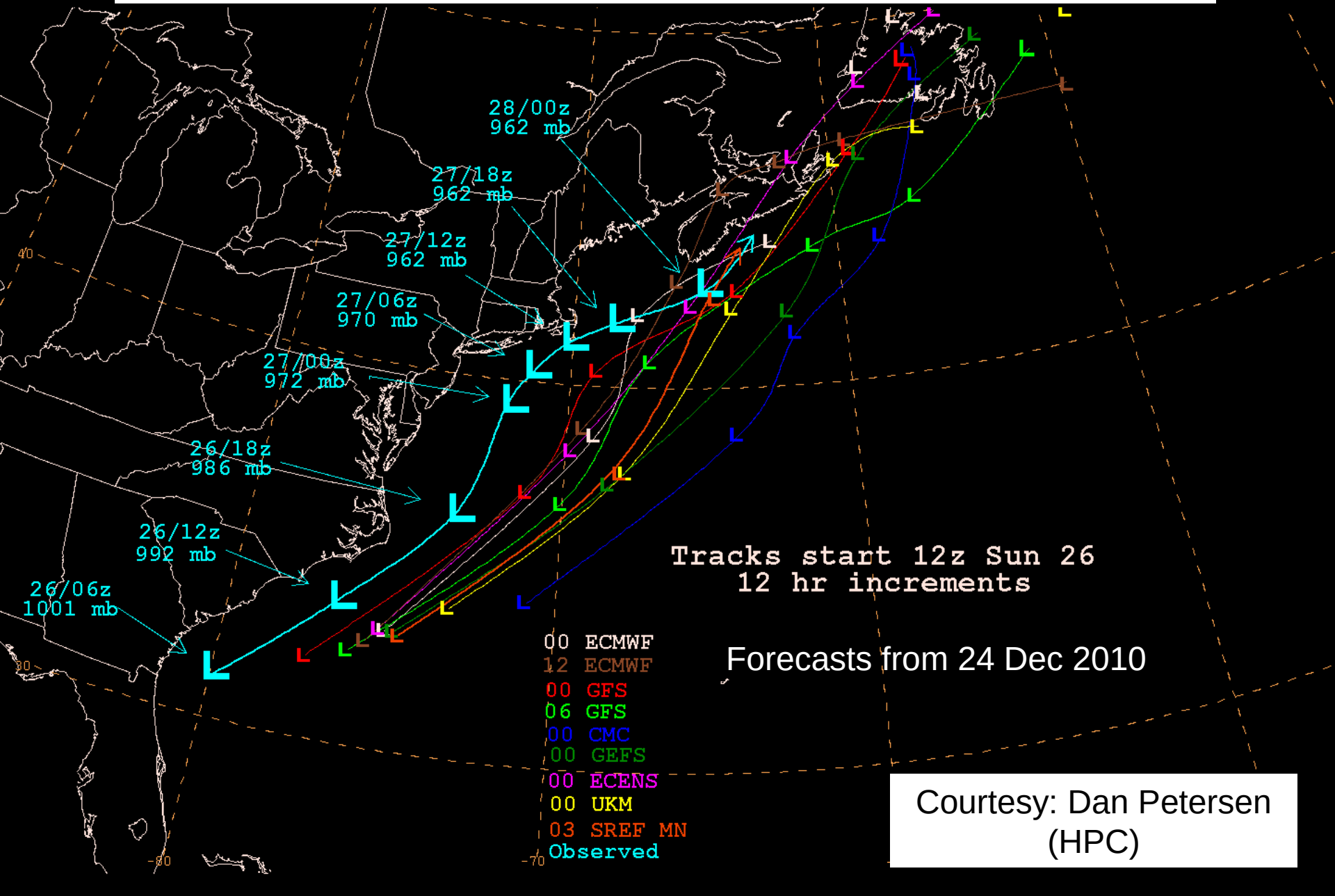


Have Developed An Automated Wave Packet Program to Determine Climo and Verify

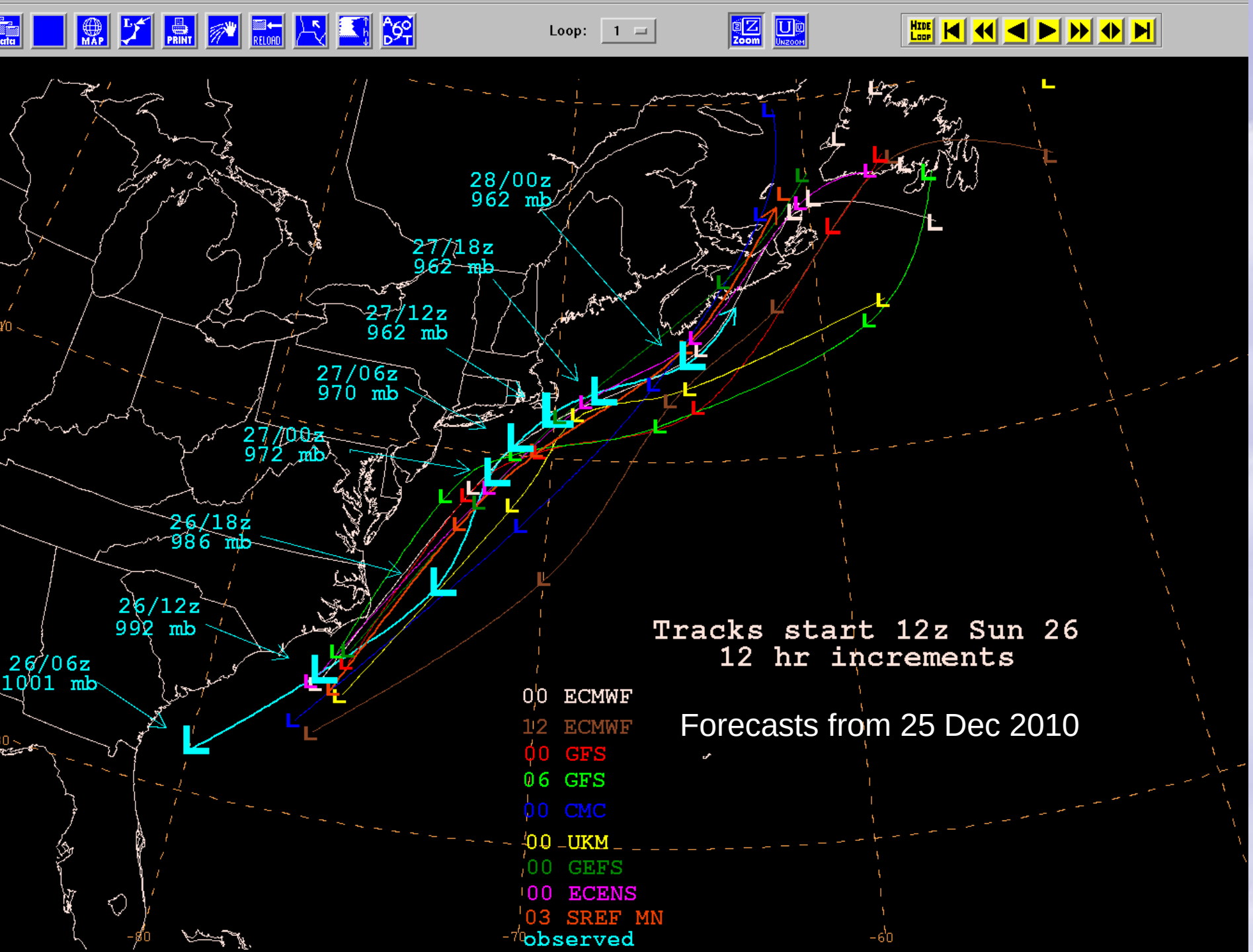


WPI Shaded, WPA in Brown Contours (15, 25, 35 m s^{-1}), 300 hPa Height contoured in black (every 24 dam). From Matt Souders: CSTAR grad student

26-27 December 2010: Solution outside envelope and flip-flopping: How can forecasters better understand these changes?



Courtesy: Dan Petersen (HPC)

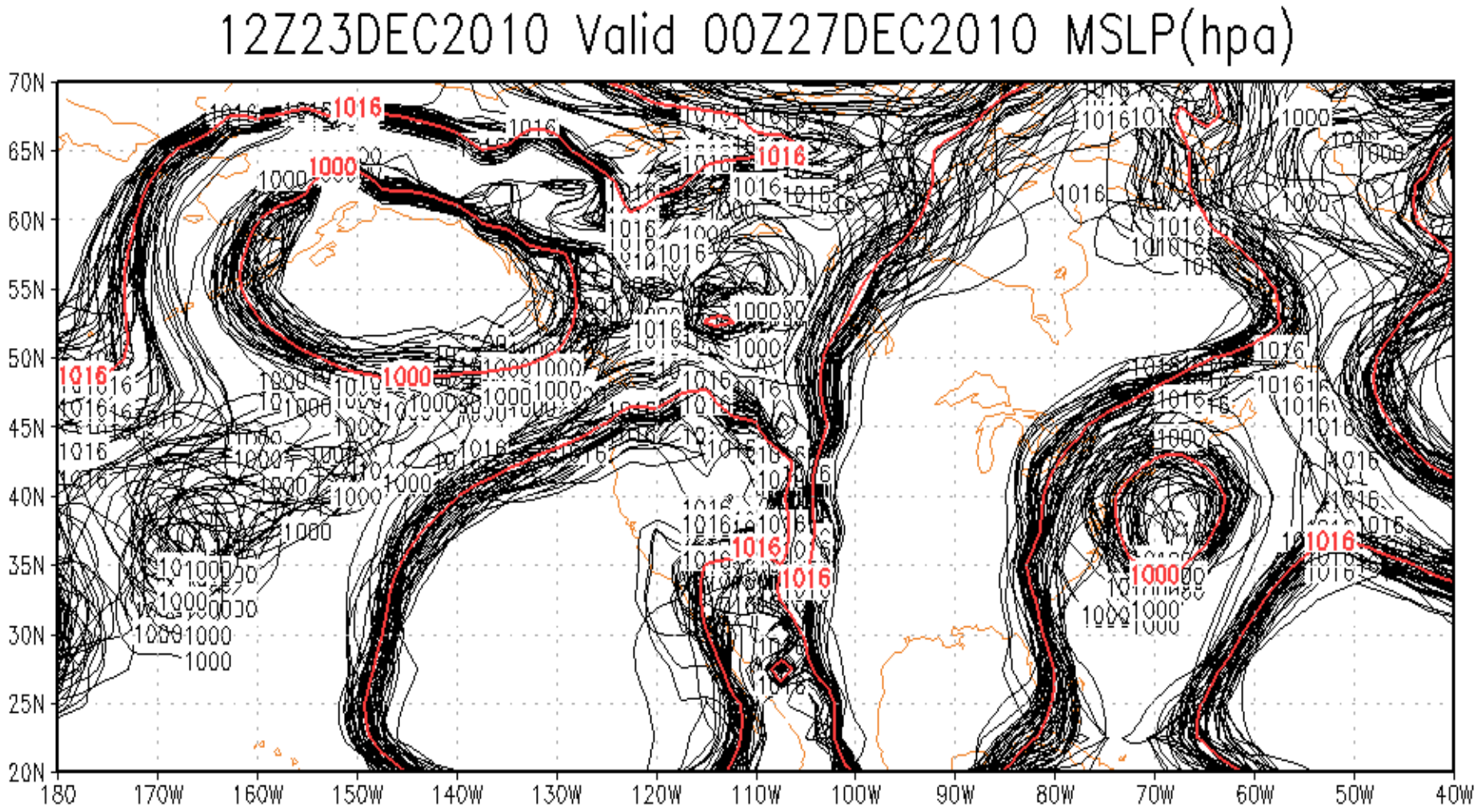

Loop: 1
28/00z
962 mb
27/18z
962 mb
27/12z
962 mb
27/06z
970 mb
27/00z
972 mb
26/18z
986 mb
26/12z
992 mb
26/06z
1001 mb
Tracks start 12z Sun 26
12 hr increments
Forecasts from 25 Dec 2010
00 ECMWF
12 ECMWF
00 GFS
06 GFS
00 CMC
00 UKM
00 GEFS
00 ECENS
03 SREF MN
observed

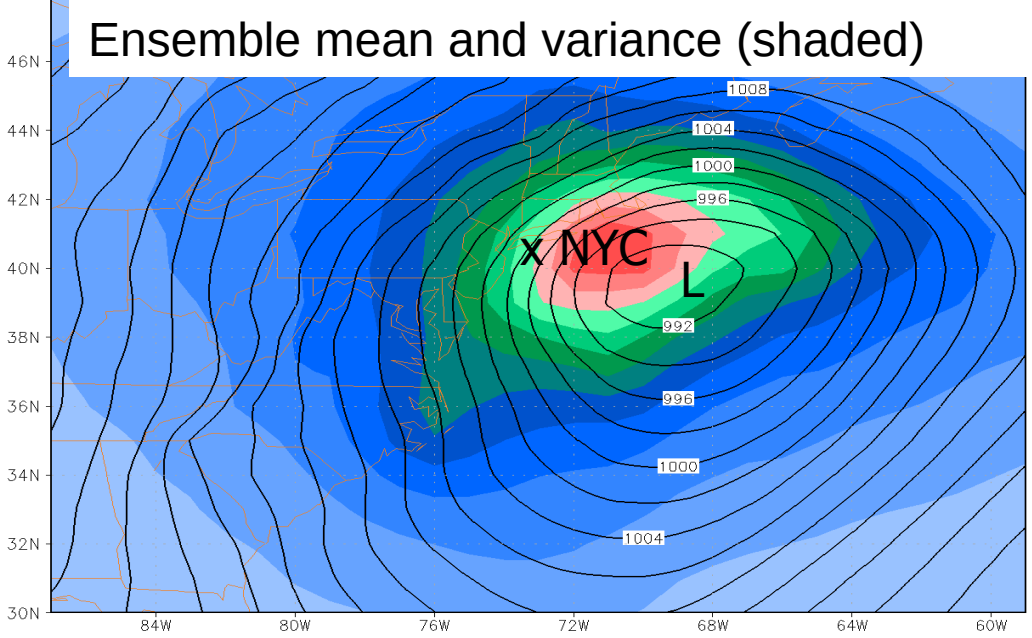
Stony Brook has developed an **ensemble sensitivity analysis** (Torn and Hakim 2008; 2009) tool to enhance forecaster awareness on how upstream uncertainty is effecting a region of interest.

* Ensemble sensitivity is a correlation between a forecast metric at the final forecast time within a boxed region and any variable within the model state vector. It makes use of the different evolution of the forecasts among the ensemble members to derive the sensitivity.

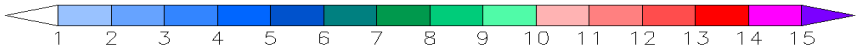
* For CSTAR: Want to use metrics useful to the forecaster: cyclone location and intensity, or why a shift in cyclone forecast between two model runs?
* Test for 26-27 Dec nor-easter and hurricane Irene
* Now running in real-time (Minghua Zheng- CSTAR graduate student)

Initial time 12 Z 23 Dec, 84 hour ECMWF ensemble forecast





0000 UTC Dec 27 2010 (84-h fcst)



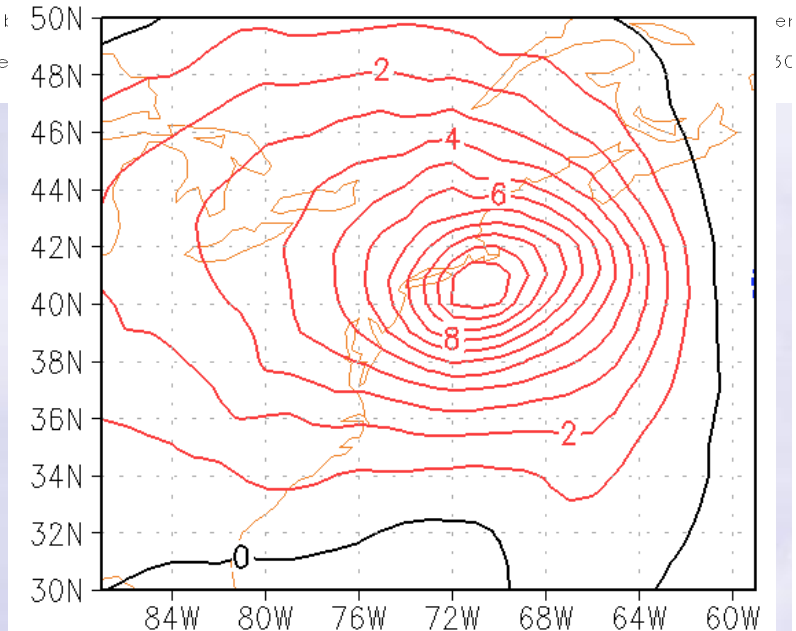
$$\text{"}Sensitivity\text{"} = \frac{\mathrm{cov}(J, x_i)}{\sqrt{\mathrm{var}(x_i)}} = cor(J, x_i) \times \sqrt{\mathrm{var}(J)}$$

J is any forecast metric at the final forecast time

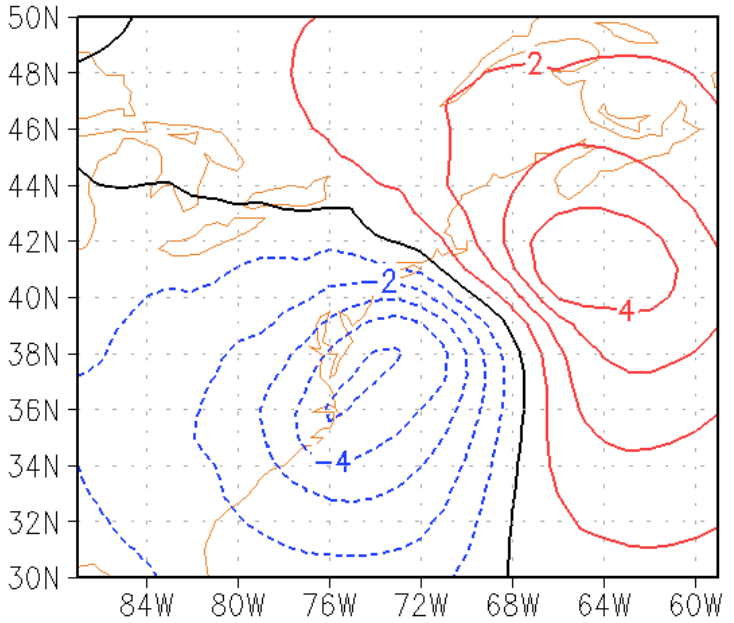
- x_i is any variable within the model state vector (500 hPa height in this example).

Here, *J* is the principal component (PC) of EOF. PCs are the projections of the dominant EOF patterns on each of the ensemble member anomalies.

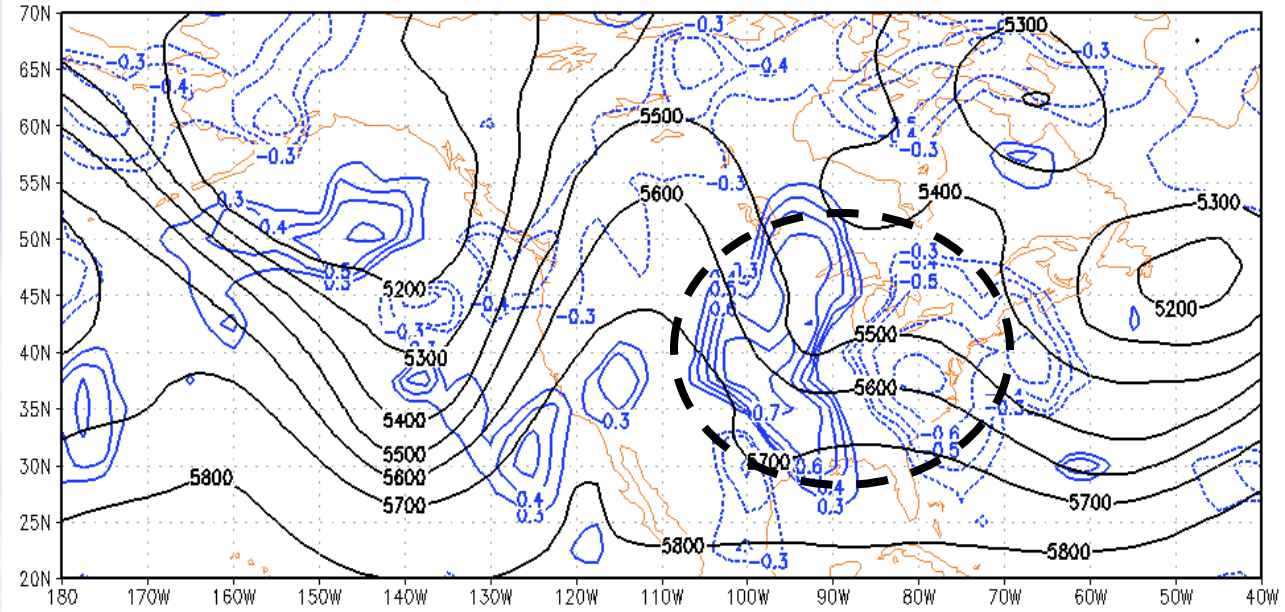
EOF1 pattern, explained variance: 54.7%



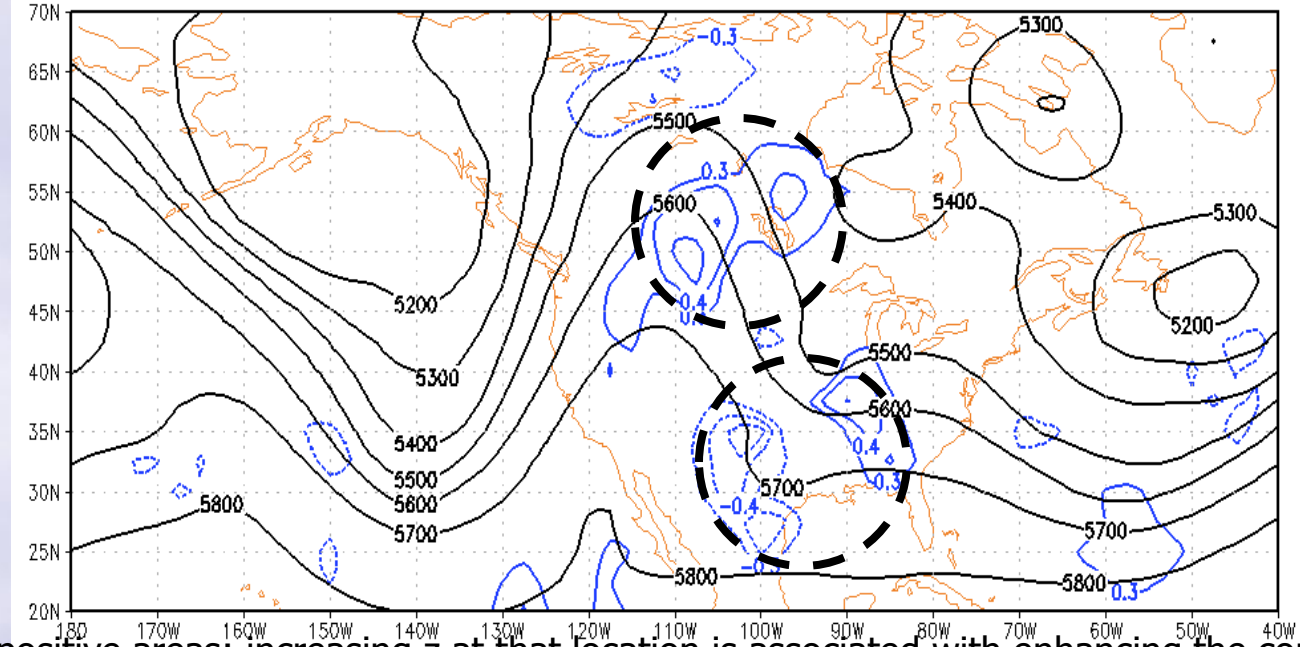
EOF2 pattern, explained variance: 26.2%



T-48 hr (25/00Z) Sensitivity



EOF1: Cyclone strength



EOF2: Cyclone position

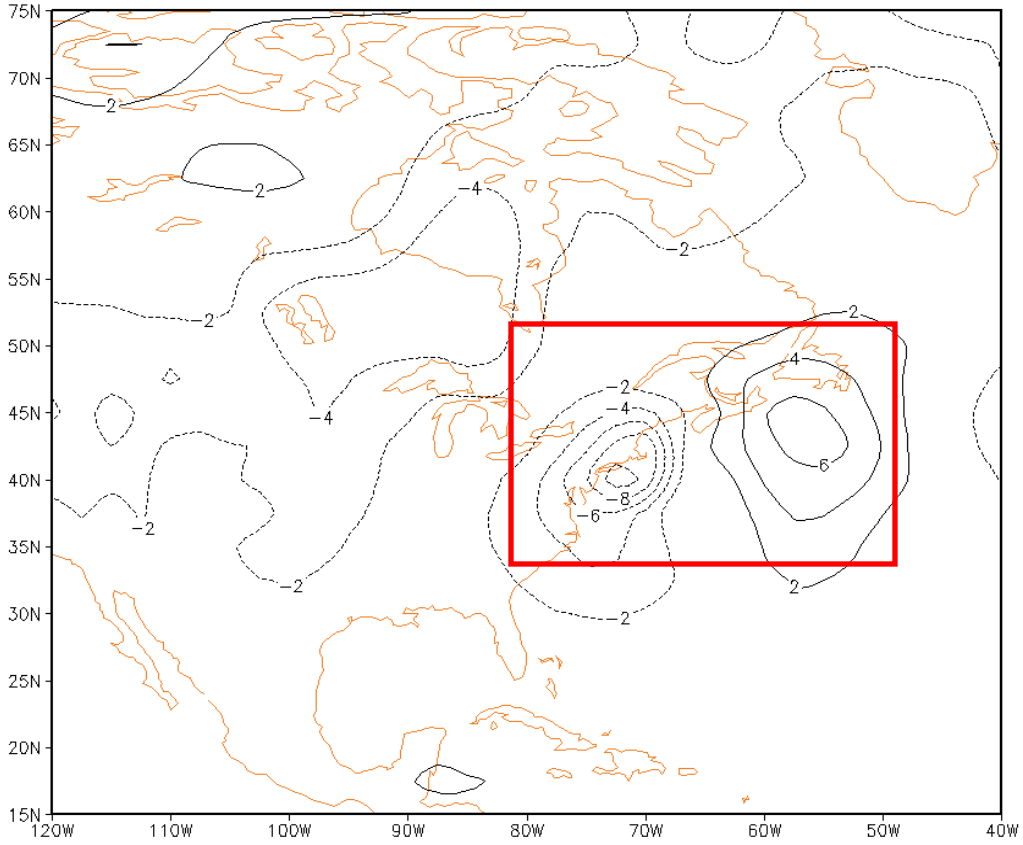
positive areas: increasing z at that location is associated with enhancing the corresponding EOF pattern
negative areas: decreasing z at that location is associated with enhancing the corresponding EOF pattern

Can also calculate the ensemble sensitivity for a box of SLP. Why the shift in cyclone position between 24/00Z and 25/00z run cycles?

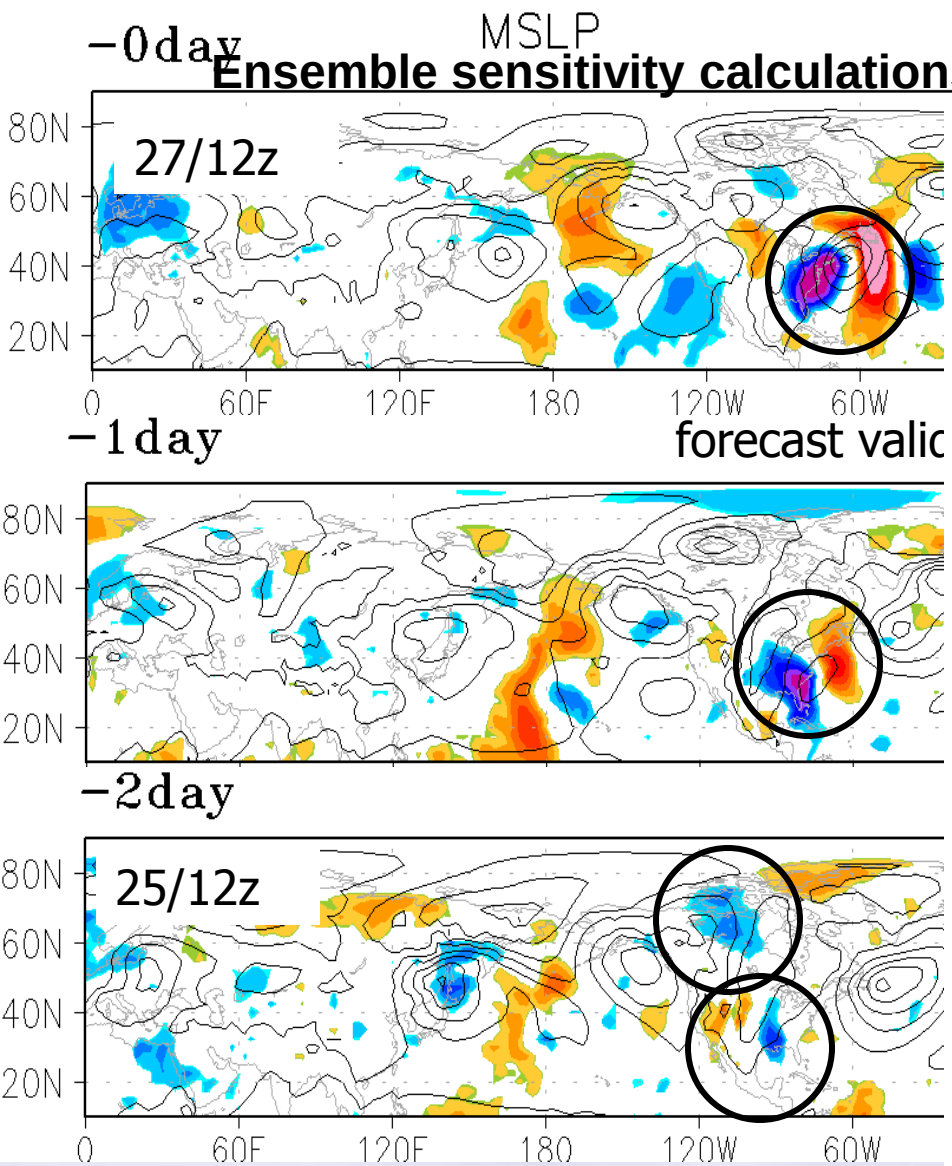
Using 50-member ECMWF, difference between MSLP ensemble mean forecast at 12z Dec 27 2010. Obtain pattern within red box.

Initial time 2010Dec2500Z (60hr) – 2010Dec2400Z (84hr)

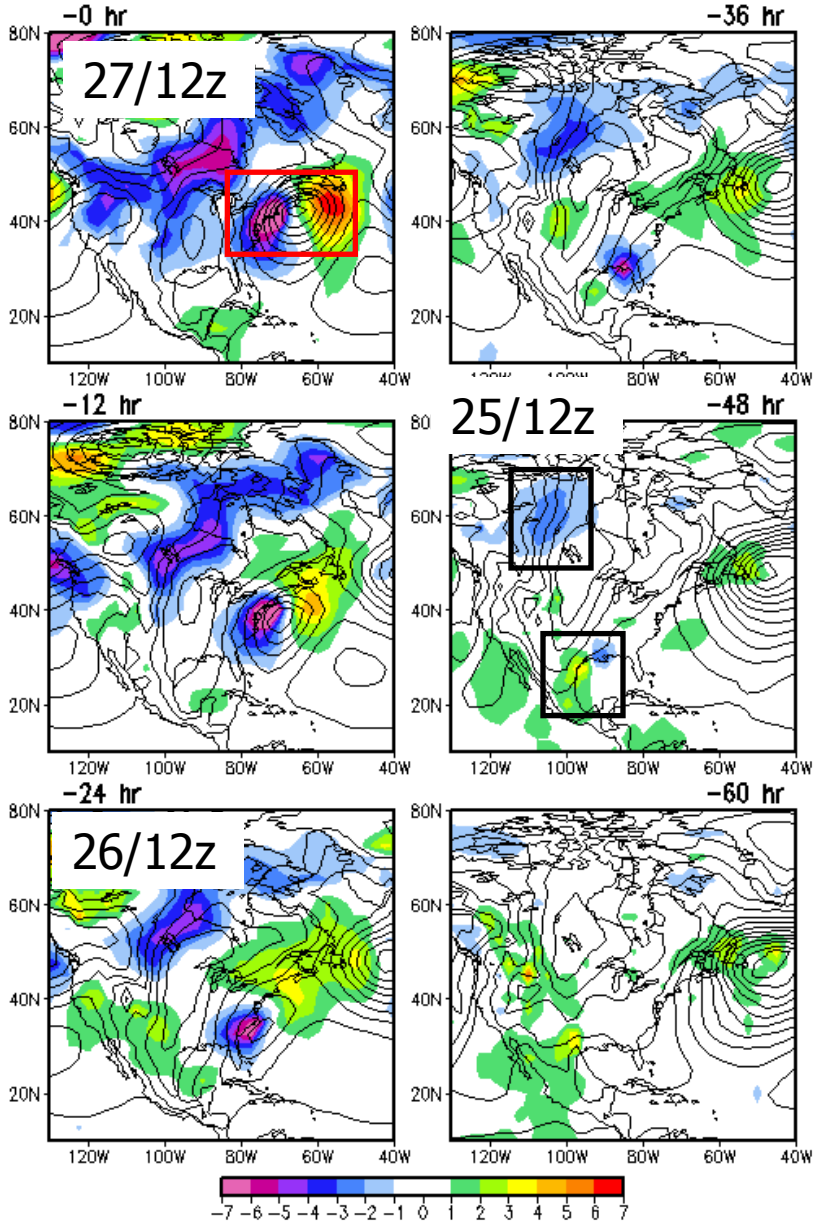
Here, J is the projection of this "shift" pattern onto each ensemble member at final forecast time (Dec27 12Z)



Ensemble sensitivity calculations



Ensemble mean MSLP Forecast difference 25/00z-24/00z



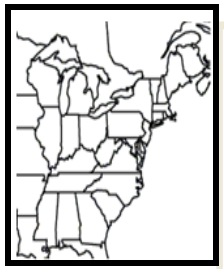
Real-time Sensitivity Calculations

CSTAR Ensemble Sensitivity Analysis Archive

02/11/2012 12Z*(Latest)*
02/11/2012 00Z
02/10/2012 12Z
02/10/2012 00Z
02/09/2012 12Z
02/09/2012 00Z
02/08/2012 12Z
02/08/2012 00Z
02/07/2012 12Z
02/07/2012 00Z
02/06/2012 12Z
02/06/2012 00Z
02/05/2012 12Z
02/05/2012 00Z
02/04/2012 12Z

For the Central and Eastern U.S. Region

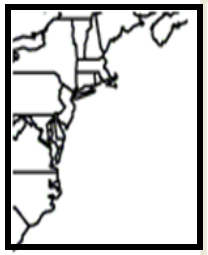
Region 1 Coordinates (longitude:95W to 65W and latitude:30N to 50N)



NCEP	NCEP_PARA	CMC	NCEP+CMC
Day 1	Day 1	Day 1	Day 1
Day 2	Day 2	Day 2	Day 2
Day 3	Day 3	Day 3	Day 3
Day 4	Day 4	Day 4	Day 4
Day 5	Day 5	Day 5	Day 5
Day 6	Day 6	Day 6	Day 6

For the MidAtlantic, NorthEast and Western Atlantic Region

Region 2 Coordinates (longitude:79W to 62W and latitude:32N to 45N)



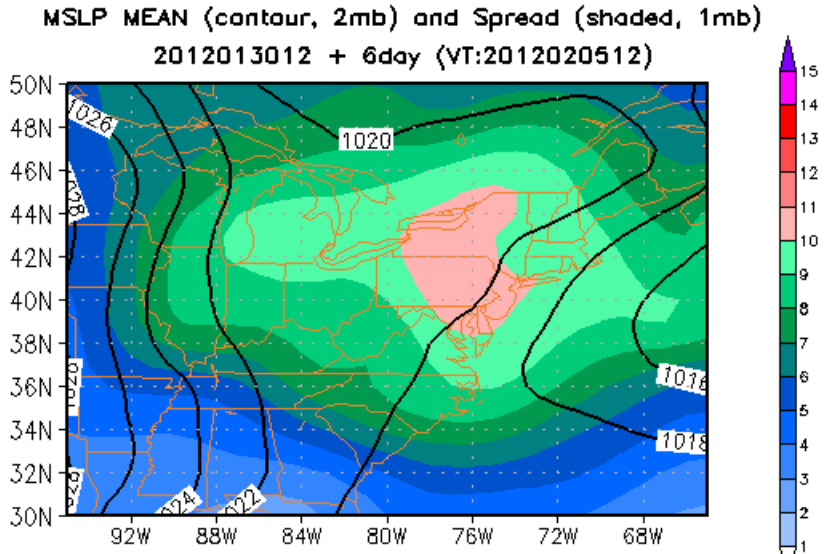
NCEP	NCEP_PARA	CMC	NCEP+CMC
Day 1	Day 1	Day 1	Day 1
Day 2	Day 2	Day 2	Day 2
Day 3	Day 3	Day 3	Day 3
Day 4	Day 4	Day 4	Day 4
Day 5	Day 5	Day 5	Day 5
Day 6	Day 6	Day 6	Day 6

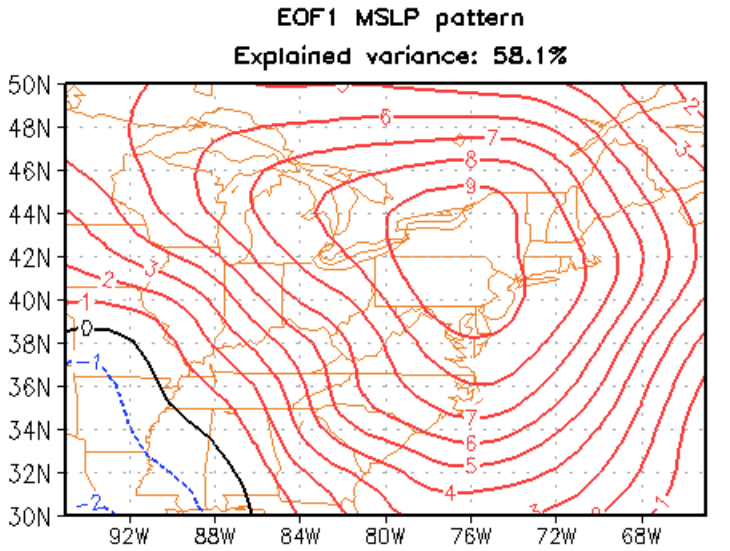
Region 3 (Floater)

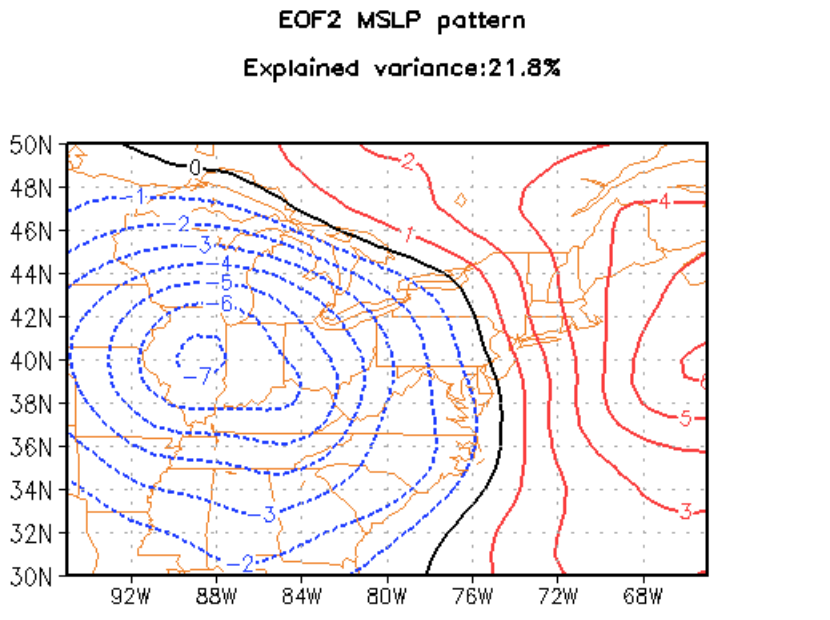
http://dendrite.somas.stonybrook.edu/CSTAR/Ensemble_Sensitivity/EnSense_Main.html

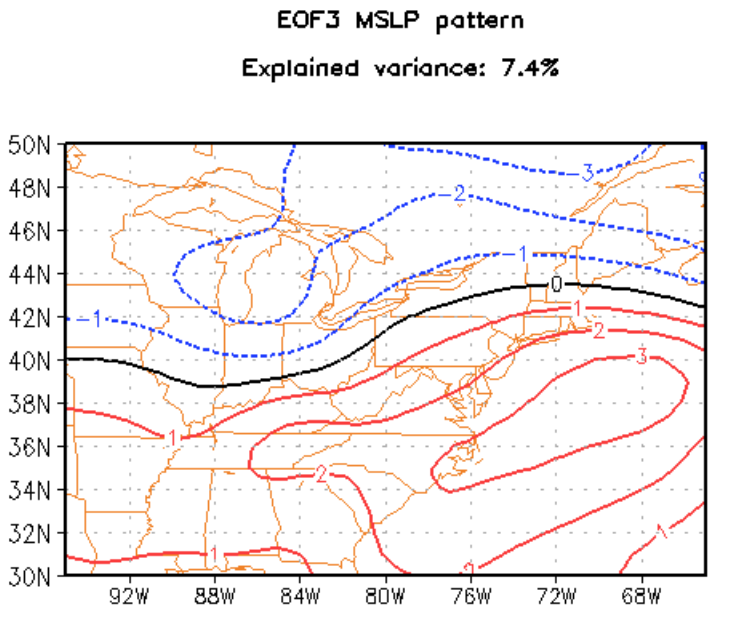
There is also an optional floater region3, in which the user can select the domain, ensemble(s), and forecast day.

Example: GEFS (6d forecast starting at 1/30/12z

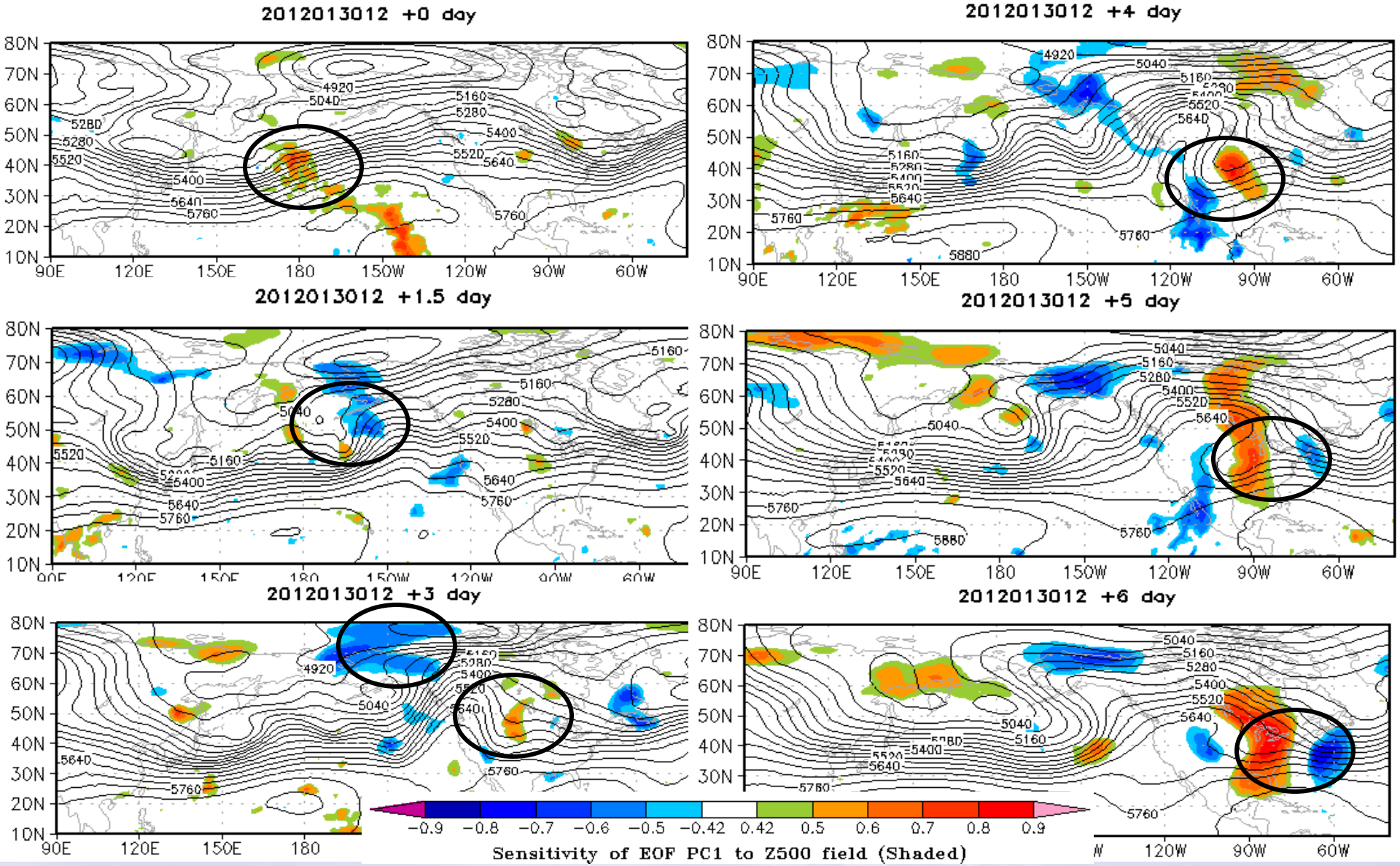








Ensemble Sensi for EOF1 from init (top left) to day 6



For the blue areas (neg sensi), if you lower the heights, it will result in the EOF1 pattern of a higher pressures (red). Positive sensi (orange) is the opposite.

Goal: Improve forecaster awareness of the important synoptic features impacting the predictability. One approach…..

1. There is a large spread is the forecast cyclone position in the ensembles. OR, two ensemble cluster means have two separate solutions? Forecaster asks: Why are some members closer to the coast and deeper than other members for a particular cyclone (ensemble cluster)?

2. Forecaster defines his/her sensitivity box around the forecast cyclone in question (forecast hour of interest).

3. Using sensitivity analysis, Forecaster can get some idea of the upstream source of the cyclone spread (Pacific Rossby wave packet in medium range?; short-wave from more data sparse Canada?, …?)

4. If the next model cycle, the storm is closer to the coast, forecaster can confirm whether it was because of changes in upstream flow that sensi analysis suggested.

Ensemble Sensitivity Summary

* Ensemble sensitivity approach has been constructed using metrics useful for the forecaster (e.g., cyclone properties). Can be expanded to other features (300Z jet, snowband position, etc…).

* The ensemble sensitivity is NCEP (thanks to Yan Luo and and Yuejan Zhu) in real-time with results on the SBU CSTAR page: http://dendrite.somas.stonybrook.edu/CSTAR/Ensemble_Sensitivity/EnSense_Main.html

* Results from 26-27 Dec 2010 sensitivity analyses suggest that:
  - Cyclone location at Dec 27 12Z sensitive to prior conditions (at -48hr to -60hr) near the gulf coast as well as over northern Canada west of Hudson Bay
  - Short range (24-hr) forecast errors over those locations from forecasts based on Dec 24 00Z apparently led to cyclone being forecast too far east.

QUESTIONS???

http://dendrite.somas.stonybrook.edu/CSTAR/cstar.html

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